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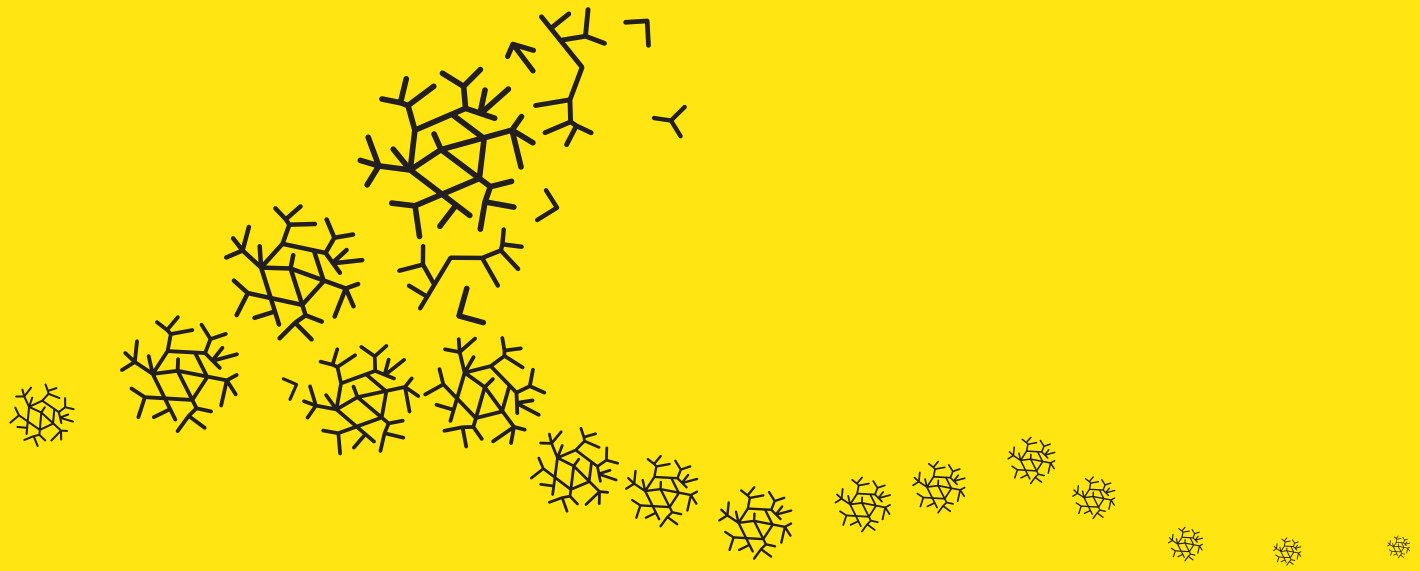
NESTA Making Innovation Flourish

The Disrupters

Lessons for low-carbon innovation from the new wave of environmental pioneers

By Rebecca Willis, Molly Webb and James Wilsdon



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Foreword

Climate change has galvanised policy communities in the UK, across Europe, and around the world. It is by definition a global problem, but also one that requires each nation, each individual to take their share of responsibility.

We are aware of the normal narratives around climate change: that it requires all of us to change our lifestyles in radical ways or that we should put our collective faith in scientists to solve the problem on our behalf. But the reality is likely to be a combination of the two.

This report starts small but thinks big: it looks at innovative technologies and approaches that already exist and that are within our grasp, but that have the potential to make a significant impact on the UK's carbon output. However, along the way these innovations are facing some unique challenges. It looks as if we might be blocking (or at least not helping) some of the innovations that might help us out the most in the short to medium term.

As always, NESTA seeks to base its policy conclusions on cutting-edge research. This time, we're pleased to have worked closely with a team from Demos. We welcome your input and your comments.

Jonathan Kestenbaum
CEO, NESTA

July, 2007

NESTA is the National Endowment for Science, Technology and the Arts.

Our aim is to transform the UK's capacity for innovation. We invest in early stage companies, inform innovation policy and encourage a culture that helps innovation to flourish.

Executive summary

A building services manager for a local council. A Cumbrian hill farmer. A high-end concierge service. And a Bath-based leadership coach. These are not the people you would expect to be pioneering solutions to climate change. Yet each of them is responsible for innovations that could put us on the path to a lower-carbon society.

We need to reduce our carbon emissions drastically. The latest reports from the Intergovernmental Panel on Climate Change show an acceleration in the rate of changes to the global climate.[1] In October 2006, the Stern Report on the economics of climate change described it as 'the greatest example of market failure that we have ever seen.'[2] Media coverage of the issue continues to grow, and politicians of all hues – from David Cameron to Al Gore, Ken Livingstone to Arnold Schwarzenegger – are grappling with its implications.

As awareness increases, a growing number of organisations are working to reduce the UK's emissions. The Government has a target, soon to be enshrined in law, to reduce emissions by 60 per cent by the middle of this century.[3] Big companies such as Tesco, Marks & Spencer and BP, now have sophisticated carbon reduction strategies.[4] Yet the debate about how to bring about a wider transition to a low-carbon society has hardly begun. Talk of wind farms, carbon offsets and hybrid cars often drowns out the bigger issues: we need to develop entirely different ways of building, travelling, shopping and even eating.[5]

In short, we need disruptive forms of innovation – cheaper, easier-to-use alternatives to existing products or services often produced by non-traditional players that target previously ignored customers. Alongside new technologies, this means recognising the importance of wider forms of innovation, such as innovation in organisational forms and business models.

A small but growing cohort of innovators are directing their creativity and entrepreneurial acumen towards disruptive innovation in pursuit of environmental goals. We call them the Disrupters. In this report we profile eight of them, but we could have found eighty or eight hundred. Each has an idea that could potentially result in significant carbon cuts. If we add up the contribution of these eight businesses, we find that already they are saving around 5.8 million tonnes of carbon dioxide a year. If each of them was to follow a medium growth path over the next five years, the total amount of CO_2 saved by 2012 would be nine million tonnes a year. This is equivalent to the CO_2 emissions of 1.6 million homes, or around three per cent of the carbon reduction target that the UK Government has set for 2050.[6]

Meet the Disrupters

This report tells the stories of eight Disrupters. More detailed accounts can be found in the Appendix.

Barnsley Council has taken one of the oldest technologies known to man – wood-burning stoves – and updated it to run municipal buildings on wood waste. Once dependent on coal, the town was hit hard by the miners' strikes of the 1980s. The Digital Media Centre is the latest in a string of buildings to convert to biomass. Richard Bradford, Principal Designer and Energy Manager for Barnsley Council, was first inspired by a trip to Austria and Switzerland. "This is so simple" he thought. "Why aren't we doing it?"

DIY KYOTO wants to bring awareness of energy use into everyone's living room. Their Wattson device is a sleek gadget which glows red when electricity demand is high and fades to blue when things are switched off. Co-founder Richard Woods says he wants to make energy visible. "What excites me about

1. Intergovernmental Panel on Climate Change (2007), Climate Change 2007: The Physical Science Basis, Summary for Policymakers, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, (IPCC, Geneva).
2. HM Treasury/Cabinet Office (2007), Stern Review on the Economics of Climate Change, (HM Treasury, London).
3. The Climate Bill, currently passing through Parliament, sets statutory targets for carbon reduction.
4. See also www.together.com, an initiative of The Climate Group, linking companies, government and citizens in ways to achieve practical action on climate change.
5. See for example The Carbon Trust (2006), The Carbon Emissions in All We Consume, (The Carbon Trust, London).
6. According to Best Foot Forward, each home produces on average 5.59 tonnes of carbon dioxide, see Best Foot Forward (2006), Domestic Carbon Dioxide Emissions for Selected Cities, (Best Foot Forward, Oxford).

the Wattson is the other changes that it will drive. It influences people's buying decisions, and companies are going to have to start responding."

GREENhomes is an environmental concierge service for Londoners. It is notoriously difficult to persuade home owners to take steps to reduce household emissions – from insulation to light bulbs, using appliances and installing renewable energy. GREENhomes takes the hassle away by auditing homes and arranging for the work to be done. "So many of the things which are really difficult problems today are not about us as passive consumers but about us as active agents. We are dealing with homeowners and behavioural change. It's not just about sticking up a wind turbine."

Baywind, based in Cumbria, is the UK's first community-owned wind farm. Run as a 600-person co-operative, it powers 1,300 homes. A new Baywind venture, Energy4All, provides support to other communities wanting their own turbines. Originally inspired by a co-operative in Sweden, the model has not yet spread to other areas of the UK, in spite of a 2004 Enterprising Solutions award from the then Department of Trade and Industry (DTI). "We see the need for a responsive, independent service to help communities meet their energy needs."

Dynamic Demand is promoting a technology which could change the way that the National Grid works. The device allows appliances like fridges to talk to the grid, and switch themselves off at peak times. If introduced across the network, this could smooth out spikes in demand for electricity, or supply from renewables, leading to huge efficiency savings, and reducing the number of power stations needed for back-up power. "There is no point in doing this halfway, we have to do it everywhere or it doesn't work. You have to prod the dinosaur until it moves in the right direction."

2OC was co-founded by entrepreneurs Andrew Mercer and Michael Edge, who realised that the pressure contained within the UK's gas pipelines could be used to generate renewable electricity. By 2014, this could be generating enough energy to remove one million tonnes of carbon from the system. Without 2OC, this technology would not have been developed because it did not fit in government definitions of renewable energy. "The way the system is set up, government doesn't have the capacity to understand developments at the fringes."

SolarStructure has created a solar-powered technology which can be fitted to windows on high-rise buildings. Like a high-tech Venetian blind, it generates power but also filters sunlight, reducing the need for air conditioning, and providing between 50 and 100 per cent of a building's energy needs. The interdisciplinary team behind SolarStructure set out to develop a product for the booming clean tech market. "It's about local power generation as opposed to grid generation – that's what's potentially disruptive."

Plan Vivo, based in Edinburgh, provides communities in developing countries with a link to global carbon markets. Richard Tipper sold the first carbon offsets in 1997, and today Plan Vivo manages a growing supply of carbon credits from agroforestry and renewable generation projects in Mexico, Mozambique and Uganda. Credits are sold to UK businesses and individuals to offset their emissions. "What we've tried to do with Plan Vivo is create a system outside the regulated carbon markets but supported by the voluntary sector on the understanding that it's still experimental."

Principles for low-carbon innovation

The Disrupters, and others like them, could help to move the UK onto a low-carbon path. But they will only succeed if they are given the right opportunities and support.

However, at the moment, the UK's regulatory and policy environment provides little help for potentially disruptive low-carbon solutions. In theory, the UK Government's definition of innovation is inclusive, but in reality most policy is directed towards the research and development of new-to-the-world technologies. The use of existing low-carbon technologies, or alternative forms of innovation, tends to be marginalised.

In recent years, innovation policy and environmental policy have, with very few exceptions, developed as separate fields. Government now needs to establish a policy, regulatory and funding framework to align these different goals. Based on our case studies, we outline four principles for low-carbon innovation policy and practice.

Keep technology in perspective. Often, innovation is seen as synonymous with the invention of new technologies. But some of the most significant low-carbon innovations

instead introduce new services or business models. Solutions to climate change are often categorised as 'technological' or 'behavioural'. But, as our Disrupters show, this division between technology and behaviour is artificial, and unhelpful. We need to look at how the two interact: how new technologies can help to change our patterns of behaviour, and how new systems, structures and policies may be necessary to allow new technologies to flourish.

Place users at the centre. Energy systems tend to treat the user as a passive consumer of energy, not an active participant. But as awareness of climate change grows, innovators are finding ways to involve individuals in energy generation and carbon reduction. In innovation thinking, too, there is a growing understanding that the user plays a crucial role in creating, shaping or testing products and services. User involvement in the energy system is still in its infancy, but a greater focus on the role of users in low-carbon innovation could open up the market to a much wider range of opportunities and solutions.

Break open closed systems. Disruptive innovation suffers because it is different. The concept of 'lock-in' describes a system in which incumbent technologies and companies have an inbuilt advantage purely because they already exist. It is difficult and expensive to pioneer new ways of doing things. For example, small-scale energy generation, like that pioneered by SolarStructure, is at a disadvantage in an energy system designed for large-scale power plants. Lock-in can be economic, as innovations will be costly to steer to market, but also organisational, social and institutional – particularly in highly regulated sectors like energy. Regulation tends to favour incumbents, not new entrants.

Make unusual connections. Low-carbon innovation comes from all corners of the economy, not just from the energy sector, or from environmental industries. Real progress can be made when a series of innovations link together, setting off a chain reaction of change. We need to think in terms of innovation 'tipping points', and create policy that supports this.

Inviting innovation

Reducing the UK's climate change impacts is an important objective for government. But policies to support innovation have, so far, been poorly aligned with climate change objectives. How, then, can government support the Disrupters and other innovators who are working to move the UK onto a low-carbon path? A number of measures need to be taken:

- First, **government should see itself as an enabler**. The UK Government has committed itself to year-on-year emissions reductions, on a clear pathway to a low-carbon economy. This needs to be supported by an enabling policy framework which sets an equally clear goal, and within which low-carbon innovation can flourish. A low-carbon 'Innovation Platform' could be the first step to achieving this;

- Second, **government should find new ways to talk to and learn from low-carbon innovators and entrepreneurs**, as an alternative to well-established companies and trade bodies;

- Third, government needs to **create spaces for experimentation**, for example low-carbon innovation zones, which combine different forms of technological, service, behavioural and organizational innovation in creative ways;

- Fourth, government needs to **rethink the way that it funds innovation**, and redirect some investment towards lower-carbon alternatives, including support for non-technological innovations, such as behaviour change;

- Fifth, **energy markets should be reformed to create better incentives for innovation**. This could be achieved through streamlining responsibility for energy and climate change, and changing the remit of Ofgem, the energy regulator, to allow it to create better incentives for innovation.

Reshaping our approach to climate change and innovation in this way would reap dividends. As well as helping reduce carbon, it could make the UK a leader in the emerging global market for low-carbon innovation – a market which, according to the Stern Review, is likely to be worth at least $500 billion a year by 2050.[7]

7. p.302, HM Treasury/Cabinet Office (2007), Stern Review on the Economics of Climate Change, (HM Treasury, London).

About the project

The Disrupters was commissioned by NESTA and written by Rebecca Willis, Molly Webb and James Wilsdon at Demos. The work was carried out over a period of five months, and involved a mix of desk research, interviews and field visits to our eight case studies. The case studies were selected to reflect a range of private, public and voluntary sector initiatives across the UK. The project was overseen by an advisory group of experts, drawn from government, academia and the business community.

Acknowledgements

We are very grateful to our Disrupters: Richard Bradford, Richard Woods, Robin Murray, Andrew Long, Richard Scott, Joe Short, Andrew Mercer, Massimo Mazzer, Nigel Foan, Neil Glover and Richard Tipper. Thanks also to the project advisory group: Andy Stirling, Charles Leadbeater, Charlie O'Malley, Tim Foxon, Stephen Hale, Alistair Keddie, Jack Frost, John Urry, Maggie Brenneke and Martin Wright; Adrian Smith at SPRU; and to Michael Harris and Richard Halkett at NESTA.

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Part I: Climate change and the case for disruption

1.1 It's time to get real about climate change

The Intergovernmental Panel on Climate Change (IPCC) is not known for hyperbole. Its reports are the product of painstaking analysis and consensus building. But in February this year, it issued its starkest warning yet. Its latest assessment, which drew on the expertise of 600 authors, 620 expert reviewers and representatives from 113 countries, concluded that average temperatures are likely to rise by four degrees centigrade towards the end of the century. The Panel concluded that temperature rises were the direct result of human action, through emission of 'greenhouse gases', particularly carbon dioxide. Climate change will result in food and water shortages, floods and extreme weather events, the displacement of hundreds of millions of people and the loss of numerous species.[8] In essence, the IPCC said that climate change will be more severe than previously thought, and its impacts will be felt by rich and poor alike.

The IPCC report comes at a time when climate change is receiving unprecedented levels of attention. Media coverage is at an all-time high, and a recent survey for the Energy Saving Trust said that over 80 per cent of people believe that climate change is having an impact on the UK right now.[9] In response to growing consumer concern, companies such as BP, Tesco and Marks & Spencer have launched ambitious plans to reduce their carbon footprint.

Political debate has also intensified. The UK has a long-standing commitment to reducing carbon dioxide (CO_2), and in 2003, the Government set a long-term goal of reducing CO_2 levels by 60 per cent of 1990 levels. The Climate Bill, currently before Parliament, will make this target legally binding, through a succession of five-yearly carbon budgets.[10] Gordon Brown predicts that this will lead to a step change in performance and accountability as "Chancellors of the Exchequer will now count the carbon as they currently count the pounds."[11] Alongside these domestic targets, the UK has made impressive efforts to secure a new round of international agreements, most notably when it chaired the G8 in 2005.

Yet despite this progress on various fronts, the UK's carbon emissions are still on the rise. They fell in the 1990s more by accident than design, when a large proportion of electricity generation switched from coal to lower-carbon North Sea gas. Indeed, the UK will meet its Kyoto target largely because of this switch. However, since then, reductions have tapered off (and have been increasing steadily from the energy sector).[12]

The Stern Review on the economics of climate change, published in October last year, poses the dilemmas in arresting terms. Stern argues that it will be more cost-effective to tackle climate change now than to cope with its consequences. But he also acknowledges that the long-term costs of climate change, and the benefits that accrue from avoiding the worst damage, are not yet being factored into economic decision-making. "Climate change," Stern says, "presents a unique challenge for economics: it is the greatest example of market failure we have ever seen."[13]

8. Intergovernmental Panel on Climate Change (2007), Climate Change 2007: The Physical Science Basis, Summary for Policymakers, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, (IPCC, Geneva).

9. See the Energy Saving Trust Green Barometer at www.est.org.uk, accessed 28th March 2007.

10. HM Government (2007), Draft Climate Change Bill, (HM Government, London).

11. HM Treasury (2007), Speech by the Chancellor of the Exchequer, the Rt Hon Gordon Brown MP, to the Green Alliance, London, (HM Treasury, London).

12. Department for Environment, Food and Rural Affairs (2007), 2005 UK Climate Change Sustainable Development Indicator and Green House Gas Emissions Final Figures, (Defra, London).

13. p.1, HM Treasury/Cabinet Office (2007), Stern Review on the Economics of Climate Change, (HM Treasury, London).

1.2 We need disruptive innovation to move onto a low-carbon path

Carbon use is embedded into everyday life. If we are to reduce our carbon emissions drastically, we will need to develop different ways of building, traveling, shopping and even eating. We will also need innovators who can help to create and use these alternative pathways to develop successful products, services and business models.[14]

However, it is difficult to predict how and where these radical shifts may occur. The temptation is to focus on the most obvious 'big ideas' – hydrogen fuel cells, carbon capture technologies, hybrid cars – and see these as the answer to our climate crisis. But solutions will come from other places too. In response to the ecological imperative articulated by the IPCC and others, a growing number of individuals, companies and organisations are thinking and investing in new ways to reduce carbon. Some of these will succeed; others will certainly fail. But cumulatively, they could produce the breakthroughs that we need for a lower-carbon society.

14. See, for example, The Carbon Trust (2006), The Carbon Emissions in All We Consume, (The Carbon Trust, London).

Large companies – the oil majors, supermarkets, electricity generators – have a vital role to play. And new technologies – whether carbon capture or offshore wind farms – will play their part. But in this report, we focus on innovations that are currently at the margins of our economy – small players, with developing business models and technologies. We use these examples partly because they tend to be overlooked by media commentary and policy support alike, but also because experience shows that significant innovations often come from outsiders, who can see different ways of doing things.

Harvard Business School academic Clayton Christensen coined the phrase 'disruptive innovation' to describe these types of change. Disruptive innovation upsets, supersedes and transforms established business models and user expectations. Examples would include the impact of iTunes on the music market, Skype on telecoms, or Ikea on home furniture. Christensen suggests that disruptive innovations often come from outside established players, and have several elements in common:

- *New consumers:* rather than trying to win customers away from existing firms or products, disruptive innovations often compete with 'non-consumption', appealing to new customers who previously lacked the money or skills to buy a product;
- *A simpler offering:* disruptive innovations frequently have lower performance on 'traditional' attributes, but improved simplicity and convenience;
- *New business models:* disruptive innovations normally come from outside the sector that they eventually overcome, and establish a new way of operating, one which often makes money at lower prices through higher asset utilisation, for example.

Christensen cites Canon photocopiers as an example. Until the early 1980s, copying was done by technicians in centralised photocopy centres, using complicated, expensive machines. Then Canon introduced desktop copiers, which were slow, lower quality and had no features like collation or enlargement. But they were simple and inexpensive, and so they caught on. Gradually, their performance improved, until they displaced large, centralised machines entirely. Canon copiers appealed to new customers – people who hadn't previously owned a copier; they were a simpler offering. They were also based on a new business model – selling a large number of small, simple machines rather than a small number of large, expensive ones.

How might we apply Christensen's model to low-carbon innovation? There are some obvious parallels:

- *New consumers:* innovations that bring in people who previously had not been consumers of low-carbon solutions, such as energy efficiency services for households who had not previously taken steps to reduce their energy use;
- *A simpler offering:* innovations that overcome some of the complexities around energy use and efficiency, and so enable consumers to take action – for example, by showing how much energy different appliances use;
- *New business models:* innovations that make profits from doing things differently, by, for example, generating electricity through small-scale renewables rather than through large power stations attached to a centralised grid.

Christensen's original analysis was aimed at encouraging innovation to propel growth and fulfil consumer needs, rather than meet a

wider, societal need like carbon reduction. But he has since developed his work and identified a new group of innovators who have societal needs in mind. He highlights the work of disruptive innovators in the healthcare field, arguing that innovation in healthcare will come from outside the sector itself, and that "what's required is expanded support for organisations that are approaching social-sector problems in a fundamentally new way and creating scalable, sustainable, systems-changing solutions."[15] This approach is needed for climate change as much as for healthcare.

In this report, we profile eight innovators who are trying to do just this. Each has an idea that has the potential to transform the way we do things, resulting in significant carbon cuts. Each is potentially disruptive, offering a new business model or service, or a simpler alternative to existing products or services. It is impossible to predict which will succeed and which will fail. But the challenge is to find ways of supporting these innovators so that they have the best chance of success.

1.3 Policies for innovation and climate change have been poorly aligned

Innovation will be central to the UK's response to climate change. It follows that climate change policy and innovation policy should be interlinked and mutually supportive. Traditionally, though, they have largely remained separate fields of policy and government action.

Climate and energy policies focus, understandably, on the easiest and cheapest ways to reduce carbon. Policies like the Climate Change Levy, a tax on the industrial use of energy, and the new European Emissions Trading scheme increase the price of carbon-based energy, encouraging greater efficiency especially in carbon intensive industries. The Energy Efficiency Commitment obliges energy suppliers to offer customers help with energy saving. But all these measures promote gradual, incremental, piecemeal change – not the type of disruptive innovation that will ultimately be required. As the Stern Review makes clear, policies that increase the price of carbon need to be accompanied by policies specifically designed to promote innovation.[16]

Since privatisation in the 1980s created a 'free market' for energy, government has been reluctant to meddle too much further. Policies that could be perceived as favouring one technology over another were rejected as distorting that market. But the energy market is not genuinely free, although it has been opened up to competition. The way that energy is bought and sold is entirely conditioned by regulation. Competition is allowed – but within tightly defined criteria. And the regulatory structures established when the energy market was privatised have worked strongly in favour of the incumbents at that time. The system prioritises price and competition – at the expense of innovation or carbon control.[17] For example, operators of the gas and electricity distribution networks have to negotiate with Ofgem, the energy regulator, to agree the charges they can levy on network users. The aim is to bring prices down, but it also restricts the capital available for research and development.

One policy, the Renewables Obligation, is specifically designed to promote innovation, through providing price support for renewable energy.[18] The record of the Renewables Obligation is, however, mixed. It has helped large-scale windfarms turn a profit. This is, in part, because such windfarms fit well within the current electricity distribution system. But, in the absence of system-wide support for innovation, it does not help other generation technologies which do not fit the system, like solar power. Such technologies find it very hard to compete in an electricity market dominated by large-scale power, even with support from the Renewables Obligation and a limited amount of grant funding. And although the Renewables Obligation is funded through levies on energy bills, very few customers are aware of what they are paying for, so there is little incentive for companies to innovate and provide services that help people to alter their energy use.

Turning to innovation policy, there has been some discussion in recent years of the links to climate change and the environment. The DTI's 2003 *Innovation Report* included a promising reference to innovation as 'essential for meeting the environmental challenges of the future – including moving to a low carbon economy and reducing waste.'[19] But the *10 Year Framework for Science and Innovation*, which was published the following year, failed to expand on how this might be achieved. Beyond a mention of the Carbon Trust and a few examples of energy research, there was no analysis of how innovation and environmental policies could be better aligned.[20]

15. p.1, Christensen, C. M., Baumann, H., Ruggles, R., and Sadtler, T. M. (2006), 'Disruptive Innovation for Social Change', Harvard Business Review, December. The term 'disruptive technology' was introduced by Clayton M. Christensen and Joseph Bower in 1995, see Bower, J. L., and Christensen, C. M. (1995), 'Disruptive Technologies: Catching the Wave', Harvard Business Review, January-February. The concept was developed further in Christensen, C. M. (1997), The Innovator's Dilemma, (Harvard Business School Press, Watertown MA), and replaced with 'disruptive innovation' in Christensen, C. M., and Raynor, M. E. (2003), The Innovator's Solution, (Harvard Business School Press, Watertown MA). See also National Endowment for Science, Technology and the Arts (2007), Innovation in Response to Social Challenges, (NESTA, London).

16. HM Treasury/Cabinet Office (2007), Stern Review on the Economics of Climate Change, (HM Treasury, London).

17. p.26, Willis, R. (2006), Grid 2.0: The Next Generation, (Green Alliance, London).

18. The Renewables Obligation places a mandatory requirement for UK electricity suppliers to source a growing percentage of electricity from eligible renewable generation capacity (currently increasing to 15 per cent by 2015). Suppliers are required to produce evidence of their compliance with this obligation to the Office of Gas and Electricity Markets (Ofgem). The Renewables Obligation is the policy responsibility of the DTI.

19. Department of Trade and Industry (2003), Innovation Report: Competing in the Global Economy – The Innovation Challenge, (DTI, London).

20. HM Treasury/Department of Trade and Industry/Department for Education and Skills (2004), Science and Innovation Investment Framework 2004-2014, (HMT/DTI/DfES, London).

While there have been some useful initiatives in this area (for example the DTI-convened Environmental Innovations Advisory Group and Defra's Commission on Environmental Markets[21]) these have tended to focus more narrowly on environmental technologies,[22] and there have been few attempts to analyse and develop policy for low-carbon innovation in its wider sense. As one recent study concludes: "Innovation, environmental sustainability and energy issues are currently addressed in separate policy regimes, each with its own goals and favoured measures and instruments."[23]

Part of the problem is that innovation in this area is often under-explored and poorly measured. NESTA has drawn attention to the substantial amounts of hidden innovation that are not picked up by traditional indicators such as formal R&D investment or patents.[24] Much of the innovation that we describe in this report is 'hidden' in this sense – relating to non-technological factors such as business models, organisational form or behaviour change. As a result, evidence-based policymakers may find it hard to address (at least, on the basis of traditional indicators of innovation).

1.4 The Disrupters are out there, but need opportunities and support

Yet reducing the UK's carbon emissions by over 60 per cent is an immense innovation challenge that will not be achieved unless policy, regulatory and funding frameworks are specifically directed towards cutting carbon. The seeds of low-carbon innovation are there, but more needs to be done to nurture them and help them grow.[25]

The Disrupters that we profile below are part of a new generation of entrepreneurs and innovators who are motivated by social and environmental goals. In a recent report, SustainAbility highlights four factors behind this trend: the growing prominence of sustainable development issues in the political and business mainstream; a sense that business is reaching the limits of corporate social responsibility as a model for addressing these issues; a new push from many large corporations for more sustainable products and services; and finally, the growth of the social enterprise movement and the 'cleantech' sector, which have 'helped push entrepreneurial solutions into the spotlight'.[26]

It is helpful to see the Disrupters as social entrepreneurs. They are, after all, fulfilling a social need – the need to reduce carbon – as well as a consumer need. They are providing a public good, carbon reduction, which is under-supplied by markets.[27] In this sense, they are similar to social entrepreneurs in other sectors, such as healthcare or education. The challenge for government is to find ways to allow innovators to make a profit from fulfilling a societal need for carbon reduction. The four principles of low-carbon innovation set out below show how this could be done.

21. The Commission on Environmental Markets and Economic Performance was established in November 2006 and will report in 2007.

22. Environmental Innovations Advisory Group (2006), Environmental Innovation: Bridging the Gap Between Environmental Necessity and Economic Opportunity, (DTI/Defra, London).

23. Sustainable Technologies Programme/Imperial College (2006), Finding the Right Policy Mix for Sustainable Innovation, (ESRC/Imperial College, Swindon/London).

24. National Endowment for Science, Technology and the Arts (2006), The Innovation Gap, (NESTA, London), and National Endowment for Science, Technology and the Arts (2007), Hidden Innovation, (NESTA, London).

25. Smith, A. (2006), 'Translating Sustainabilities between Green Niches and Socio-technical Regimes', Technology Analysis & Strategic Management, July.

26. SustainAbility (2007), Growing Opportunity: Entrepreneurial Solutions to Insoluble Problems, (SustainAbility, London).

27. National Endowment for Science, Technology and the Arts (2007), Innovation in Response to Social Challenges, (NESTA, London).

Part II: Four principles of low-carbon innovation

2.1 Keep technology in perspective

Barnsley, in South Yorkshire, once made all its money from fossil fuels. For decades, the town lived off its coalmines, and it is still home to the National Union of Mineworkers. Following the strikes of the 1980s and the subsequent pit closures, Barnsley's economy was almost wiped out. But today, it has the feel of a place on the mend. A car park in the town centre is being transformed into a new Digital Media Centre. And this high-tech showpiece, one of the flagships of Barnsley's regeneration, will be heated by one of the oldest technologies known to humans: wood.

Barnsley is blazing a trail for biomass. The Digital Media Centre is the latest in a string of biomass-heated buildings – blocks of flats, the civic headquarters, libraries and schools. Biomass, in the form of woodchip from trees, is a renewable resource. It is also home-grown: much of the wood that Barnsley uses comes from within the borough, in the form of wood waste from municipal parks.

The inspiration for Barnsley's biomass came from Austria, where woodchip and wood pellet boilers are commonplace. Richard Bradford, Principal Designer and Energy Manager for Barnsley Council, is nothing short of evangelical about biomass. A tour of Austria and Switzerland made him think "this is so simple, so easy. Why aren't we doing it?" So he came home and got started. He wrote a biomass policy to take to the Council, in June 2004, and simultaneously won funding from Yorkshire Forward to conduct a trial of wood pellet boilers in municipal buildings. Although it had never been done before, the Council trusted Richard's track record in building maintenance and design, and gave him the green light for biomass heating.

Richard's first project was a social housing estate in Sheffield Road. Three blocks of flats had been heated by coal boilers, with heat provided to tenants at a flat rate charge. But the boilers were on their last legs along with the rest of the heating system, and so were replaced with two woodchip boilers, to provide heat and hot water to 166 flats. It's a simple process. Each week, a truck arrives loaded with woodchips cut from tree waste. The wood is stored in a bunker just outside the flats, and fed into the two boilers automatically. An energy management system monitors how much heat is needed, and the boilers adjust their output accordingly. Tenants now pay upfront for the heat and water that they use, through charging a smartcard at the local pub or post office. Because they pay per unit, there is an incentive to be energy-efficient. Each flat has its own timers and heat controls.

The Sheffield Road project was so successful that others followed – including the new Westgate Plaza One civic headquarters, the council Depot at Smithies Lane, the Central Library, and branch libraries, schools and leisure centres. Richard now spends a significant amount of time promoting the biomass model to other local authorities, who see Barnsley as a trailblazer.

2.1.1 New or old?

Barnsley's biomass scheme is certainly innovative. But as Richard says, "it's not rocket science, it's just new thinking for this country." Innovation discourse tends to focus on patents and gadgets, rather than new business models or new ways of doing things. Read any account of the industrial

revolution, and it's likely that the stars of the show will be the new technologies – the spinning jenny, James Watts' steam engine. But the real breakthroughs came just as much from non-technological advances. Josiah Wedgwood made his fortune not by innovating a new type of pottery, but by developing new organisational techniques. Previously, craftsmen had produced pottery on a piecework basis; Wedgwood instead hired a workforce, set up a factory, broke the tasks down into specialised areas, and began mass production.

The same assumptions about the centrality of new technology are made about today's innovations. Mention the low-carbon revolution, and thoughts tend to turn to wind turbines, solar panels, maybe the new carbon capture technologies that trap and bury carbon dioxide before it's emitted into the atmosphere. But other breakthroughs may be equally, or more, important. Finding a way to make householders draught-proof their homes requires considerable ingenuity, as GREENhomes is discovering, although the technology is nothing new. Barnsley's scheme actually goes backwards, in one technological sense, by replacing coal with wood. But its innovation stems from the way it is planned and executed.

David Edgerton warns of the dangers of emphasising novelty, invention and innovation, rather than the prosaic but ultimately more significant aspects of technology in use. "Too often," he writes, "the agenda for discussing the past, present and future of technology is set by the promoters of new technologies."[28] Rather than concentrating our efforts on supporting the new, then, we should be looking at what we can do with what we have. This is what drives change: "most change is taking place by the transfer of techniques from place to place."[29] Many of the Disrupters we profile, including Barnsley, Baywind and 2OC, were inspired by happenings elsewhere in Europe.

Government does acknowledge the role of non-technological innovation. The UK Government's definition of innovation, 'the successful exploitation of new ideas,' is a deliberately inclusive phrase. But over and over again, rhetoric of new technology pervades government accounts of innovation. No ministerial speech on climate change is complete without a reference to new technological solutions. This bias towards new technologies makes life very difficult for those trying to innovate through other means. But it makes it hard for technology-based innovations as well, because it does not take account of the many factors that impede or constrain innovation; in other words, it focuses on invention, and not the longer-term processes of development, adoption and diffusion.

2.1.2 The end of the line

Wiebe Bijker's account of the emergence of the modern bicycle shows that a technology does not develop along a smooth path toward dominance. Leonardo da Vinci sketched a machine remarkably similar to what today we think of as a bicycle – two evenly-sized wheels, powered by pedals and a chain. The first commercially-available model, however, did not emerge until 1879, when H. J. Lawson, manager of the Tangent and Coventry Tricycle Company, took out a patent on a bicycle powered by a chain on the rear wheel. But this bicycle was a commercial failure; the most popular bikes of the day were so-called 'Ordinary' bicycles, with one huge wheel turned directly by feet on pedals, and one small. It took a further eighteen years for the modern bicycle to become popular.

Most accounts of bicycle innovation see the high-wheeled varieties as a failure along the route to the dominant model. Bijker, however, argues that the high-wheeled Ordinaries should not be thought of as a detour, but, as seen by the relevant social groups of the time, "a comfortable, classy, well-working artefact."[30] He stresses the importance of analysing not just the technology itself, but its place in society. There was nothing inevitable or automatic about the eventual emergence of the modern bicycle. As Bijker writes, "once students start expecting linearity, they blind themselves to the distortions that linear descriptions almost inevitably require."

Similarly, David Edgerton writes that "alternatives exist for nearly all technologies: there are multiple military technologies, means of generating electricity, powering a motor car, storing or manipulating information, cutting metal or roofing a building. Too often histories are written as if no alternative could or did exist."[31]

Flawed but ingrained assumptions about the relationship between science, technology and innovation lie behind this obsession with novelty. Despite reams of evidence to the contrary, most policies implicitly characterise innovation as a pipeline, where basic scientific research is fed in at the beginning, leading to

28. p.ix, Edgerton, D. (2006), The Shock of the Old: Technology and Global History Since 1900, (Profile Books, London).

29. p.209, ibid.

30. p.97, Bijker, W.E. (1997), Of Bicycles, Bakelites and Bulbs: Toward a Theory of Sociotechnical Change, (MIT Press, London).

31. p.209, Edgerton, D. (2006), The Shock of the Old: Technology and Global History Since 1900, (Profile Books, London).

some technological innovation, and a product emerges at the end of the pipe.

One example of how embedded this view is can be found in a recent Government paper describing the new Energy Technologies Institute (ETI), which has been set up to fund and co-ordinate research into sustainable energy technologies. The paper focuses heavily on the process of getting new technologies developed, demonstrated and deployed – in that order. Their diagram outlining the government support needed for each of these stages makes the 'pipeline' clear (see below).

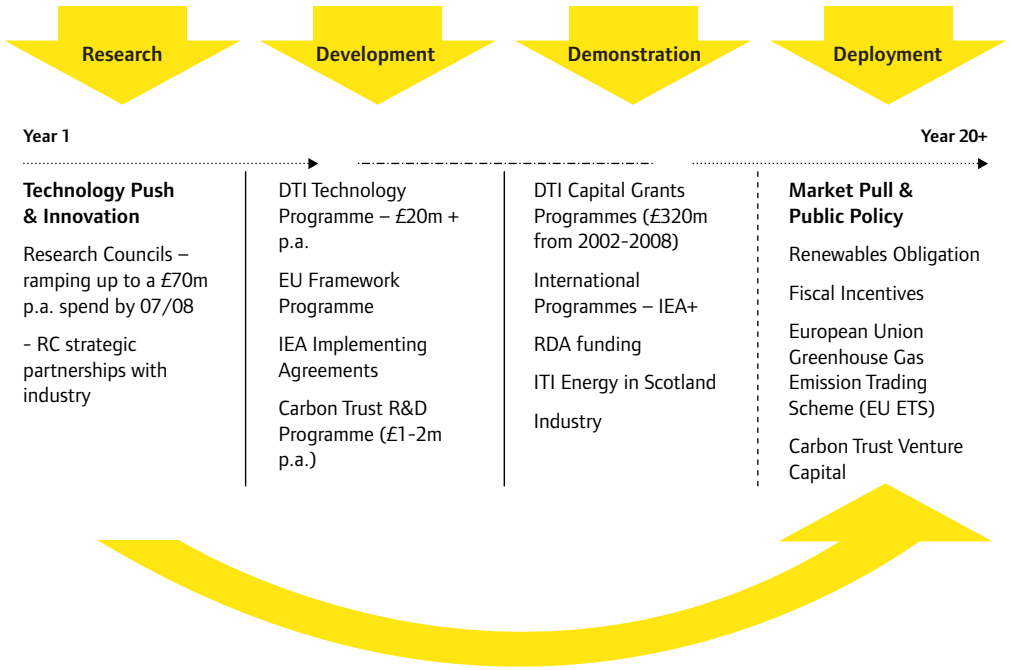
The arrow at the bottom of the diagram mentions 'non-technical barriers'. In such a way, all of the huge questions of implementation, application and institutional setting within which the technology will operate are banished to a small arrow.

The paper is strangely silent on the place of each technology in our society or economy, or on what else needs to change to allow each particular technology to flourish. This approach is all the more worrying if you look at the range of technologies that the new Institute aims to support. Included in the list are a number of technology groups, such as combined heat-and-power, and energy efficiency and demand reduction in buildings, whose technical efficacy is not in doubt. The reasons that they have not yet been deployed are varied – we go on to describe below the problems of 'lock-in' which prevent some technologies from flourishing. But they have not failed because of a technological shortcoming that technological innovation alone could overcome. They have failed because the social, institutional and policy environment is not conducive to their development. If followed slavishly, the process described in the EIT paper will do very little to help with this.

A pipeline view cannot explain many areas where innovation occurs. Nor does it seem to provide a strategy for managing innovation in complex areas where we confront new problems and need to support change. In other words, a pipeline model over-simplifies the social complexity of any wave of change, reducing the actions of the user to their purchasing decisions.

32. p.3, Department of Trade of Industry (2006), Energy Technologies Institute - Additional Information, (DTI, London).

Figure 1: Policy support for energy innovation



Source: DTI.[32]

2.1.3 Energy efficiency hits the lifestyle magazines

The Wattson is another example of an existing technology finding a new use: in this case, a gadget that turns measuring energy into a lifestyle statement. One of the Wattson's creators, Richard Woods, says that he hopes it can do for energy efficiency what the iPod did for music. The Wattson is a small machine which reads the power being used across the home, and displays it in watts or pounds. It glows different colours according to how much power is being used, fading to a cool blue when most appliances have been switched off.

Like the iPod, Richard wants the Wattson to be a lifestyle product; sleek, sexy, personalised, something that people talk about, compare, and swap tips on. It is very design-led, as he explains: "eco-chic is almost a term invented for us. We were described in one newspaper as 'a curving slab of loveliness.' We've exhibited in Milan." In short, the Wattson is about "taking dull information and making it something people want to get involved in." With the iPod comes iTunes, and the ability to share music selections and create communities of iPod users online; similarly, Woods' ambition is to link Wattson users through the web. Each Wattson has a USB port, and data from each household could be uploaded, compared, bragged about, criticised.

The technology behind the Wattson is nothing new – it uses radio waves to transmit the information. They don't even hold the patent. As Richard says, "We're not too worried about patenting. It's the brand that's the important bit." The crucial thing, for Woods, is what the Wattson enables: "what really excites me about the Wattson is the other changes that you'll drive through. Not just the people who buy this and make a few changes in their own life; once you're more aware, it becomes one of the factors in your buying decisions. So other companies are going to have to start responding."

The Wattson is a gadget. But it doesn't fit neatly into any typology of technology. It's not a low-carbon substitute for a high-carbon incumbent. It doesn't reduce carbon in its own right – in fact, it needs electricity to power it. Its reason for existence is to support behaviour change – to enable people to understand and act on carbon use within the home.

2.1.4 Time off for good behaviour?

Solutions to climate change tend to be categorised as technological or behavioural. Technological solutions, the story goes, are those that come about through innovation, developing a low-carbon technology to substitute for a high-carbon one. And so hybrid cars replace conventional petrol engines; wind power replaces coal. The assumption is that substitution can take place if the low-carbon substitutes become competitive, through market forces or government support. Then, according to this story, there are also the behavioural solutions, which involve persuading people and organisations to do things differently – driving less, using less power. The word 'innovation' is rarely used in accounts of behavioural solutions.

This juxtaposition between technology and behaviour leads to an unhealthy dependence on new technology as the solution. Selling behaviour change – particularly pitched in terms of abstinence or cutting back – is not the stuff of speeches. It is fraught with political difficulty. Selling technology is much easier. In a particularly candid interview with Sky News, Tony Blair admitted that he thought it was pointless to ask people to change their behaviour significantly:

> *"I think it's a kind of false argument to say to people, you know, unless you're prepared to put on a hair shirt you can't really deal with this issue. It's not true – you can deal with it through developing the science and technology."*[33]

When behaviour and technology are separated out, as Blair suggests, then innovation remains purely in the technological domain. Attempts at behaviour change, on the other hand, become an innovation-free zone. The Government's latest awareness campaign, Act On CO_2, offers a rather desultory list of climate-friendly chores that one suspects Tony Blair wouldn't sign up to, such as walking a short distance rather than driving, drying clothes outside rather than in a machine, and only part-filling a kettle.[34]

Worryingly, through campaigns like this one, responses to climate change become an individualised pursuit. Yet people are reluctant to change their behaviour unless others will do likewise. There is an understandable cynicism about free riders. Eurobarometer work has shown that people "want their actions to be part of a wider solidarity."[35] So separating behavioural change out, and seeing it as a separate sphere of action – and one immune to innovation – is problematic.

33. Tony Blair, interview with Sky News, 9th January 2007.
34. See http://actonco2.direct.gov.uk/index.html

Instead, innovation like the Wattson, which supports behaviour change and potentially turns it into a collective endeavour, should be sought out and encouraged. Other examples of behavioural innovation are emerging, too. The RSA's new online carbon trading scheme for individuals, CarbonDAQ, allows people to calculate their carbon emissions and compare them to others.[36] Similarly, the Climate Group's new initiative, We're in this Together, provides a forum for individuals to pledge carbon reductions, offers help with meeting the pledges, and accumulates pledges to provide overall carbon saving figures.[37]

Far from separating technology from behaviour, the intricate links between the two should be acknowledged. However, we have a pressing need to develop a more sophisticated account of behavioural innovation, as a vital ingredient in tackling climate change.

2.2 Place users at the centre

As awareness of climate change grows, people are beginning to look at what they can do to reduce their own carbon emissions. But the picture can be confusing. Should they opt for solar panels, a wind turbine, or perhaps just better insulation? How much money will they save on their electricity bill, and what kind of grants are available? Where can they get impartial advice and who can do the work?

This is where GREENhomes comes in. Backed by the London Climate Change Agency, GREENhomes provides a concierge service to householders who want to cut their carbon. The service starts with a home visit and a detailed energy audit, which forms the basis of advice on home energy generation as well as efficiency. There is then help with finding suppliers and implementing any changes. Crucially, the service is personalised according to people's outlook, budget and aspirations, as well as to the conditions of their house.

Such a bespoke, personalised service is highly unusual in the energy market. The idea of users as producers, or even as innovators, has gained momentum in some sectors, but the energy system is still based on a traditional, centralised model of large generators sending power down the wires. The journey from producer to user is long in physical terms – power stations tend to be in remote places – but also psychologically. Users have traditionally been treated as passive consumers of a standardised range of products, with choice reduced to deciding between British Gas, nPower or Scottish Power.

Although suppliers are increasingly being asked by government to help their customers with energy efficiency measures, this remains a secondary concern, and is not part of most companies' core business. In general, helping people to understand and reduce their energy use is something that has been left to public awareness campaigns, usually by local authorities or government agencies.

This is why GREENhomes, with its relentless focus on the needs of individual users, is such a breath of fresh air. The idea grew out of Robin Murray's time in Canada in the early 1990s. He was involved with a programme called Green Communities, which created jobs in alternative energy development at the same time as tackling carbon emissions. It provided energy, water and waste assessments for homes, and then made citizens in each community responsible for devising their own reductions in emissions. Often the citizens seemed more incentivised by comfort and cost than carbon reduction, but in the end what they had were community plans and practice for reducing carbon.

Robin realised that encouraging behaviour change required an appeal to people's needs and aspirations, rather than worthy exhortations to be green. A spell at the Design Council allowed him to experiment with user-centred approaches to healthcare, and he began to think about how to apply them to energy. Then he met Alex Cheatle and Andrew Long, the co-founders of Ten, a lifestyle management service for busy Londoners. Ten's business model is simple. For a monthly subscription, members get access to a Lifestyle Manager who will sort anything out for them – from booking concert tickets to finding a plumber. Robin realised that Ten's experience of working with individuals in this way would make them perfect partners for his GREENhomes idea. As Andrew explains, "It's about building the relationship and trust with the client; using knowledge well; managing supply chains and expectations. That's what we know about."

Ten understand that their clients are the source of real value in their business. Their knowledge management system has evolved into a unique database consisting of every single client and supplier interaction over the lifetime of their business. "Its function is to share best practice. Every job has to be categorised and linked to

35. Eurobarometer (2002), The Attitude of Europeans Toward the Environment, (European Commission, Brussels).

36. See www.rsacarbonlimited.org

37. See www.together.com

a member and supplier," says Andrew. "We put feedback in each time we do a job and then the ratings of the suppliers change in real-time. It's a massive system." Without that accumulated feedback from clients and suppliers, their concierge service would not exist.

2.2.1 The distributed generation

GREENhomes offers us a glimpse of how environmental services can be designed around user needs. But it is still at the modest end of the spectrum of user involvement in innovation. A more radical example can be found on Harlock Hill, a few miles north of Ulverston in Cumbria. On a crisp, sunny winter's day, a biting wind blowing in from the Irish Sea turns five wind turbines. Turbines are no longer an unusual sight on our hills, and perched in a field surrounded by grazing sheep, they don't look at all exceptional. But they are – this is the UK's first co-operatively owned wind farm.

The Baywind turbines started turning in 1997. A farmer looking for other ways to generate income got talking to a local man, Keith Boxer, who knew about a successful wind farm co-op in Gotland, Sweden. Keith brought the Swedish company, Vindkompaniet, over to Cumbria, and they saw a chance to get a foothold in the UK market, so offered to support the project. Some local people weren't so enthusiastic: Ulverston town council voted fourteen to one against the turbines, and the only positive vote came from councillor Richard Scott, who was then invited onto Baywind's board. Negotiating the project through the complexities of planning was quite a challenge, but permission was eventually granted and, in October 1996, Baywind issued its first share offer. Despite being "asked for cheques in return for little more than a promise", 600 people, many of them local residents, invested a total of £600,000, enough money to buy one turbine. Vindkompaniet financed the other four turbines.

The opening ceremony brought typical Cumbrian weather – plenty of wind and horizontal sheets of rain. But 300 of the shareholders turned out to see their investment spin into action. Since then, they have enjoyed steady returns of around six percent a year, and will recoup their original stake at the end of the twenty-year lifetime of the turbines. The scheme has proved popular: two years after the original share offer, another offer was put out, and Baywind raised enough to buy a second turbine from Vindkompaniet.

It is easy to dismiss Baywind. Its electricity output is tiny compared to other wind farms. Its carbon saving in a year is equivalent to the amount generated by one return flight to Australia. But if other communities followed suit, the aggregated benefits could be significant. Baywind has set up a spin-off venture, Energy4All. This development company works with other communities interested in setting up co-operatively owned wind farms. They have just started construction of a £4.5 million windfarm at Westmill in Oxfordshire, with more plans in progress elsewhere. And experience from Denmark and Germany suggests that community ownership can work on a larger scale. Both countries have significant quantities of wind power, with around 80-90 per cent owned by small investors.[38] An added advantage of such a model is that communities are more likely to support wind farm developments when they have a stake in them. This may prevent the fierce opposition that has blighted many large-scale wind farm proposals.[39]

Taken together, the innovations in service design and ownership being pioneered by GREENhomes and Baywind illustrate the fundamental shift in our energy system that is becoming possible. They are leading the way from a system that is centralised and distant from the users of power, to one that is localised and involves people. From a system which gives little opportunity for feedback, to one which provides two-way flow of information. From a system which trades in units of energy, to one which trades in efficiency of outcome. In short, a user-centred energy system which harnesses producers and users in a framework of co-operation to make the most of a scarce resource.

But this vision will only be achieved if energy markets, and the regulations that shape them, are opened up. Governments need to ensure that the market of the future is accessible to a wider variety of players: individuals selling home-generated power; community-owned renewable companies like Baywind; energy service providers like GREENhomes; and large commercial operators.

2.2.2 Towards user-centred innovation

Both GREENhomes and Baywind reflect a broader shift toward a focus on users as creators of value. But in other sectors this shift towards user-centred models of innovation has gone further. The influential MIT professor Eric von Hippel points to examples of user-centred innovation in sectors such as sports equipment, where keen windsurfers and snowboarders

38. Szarka, J. (2006), 'Wind Power, Policy Learning and Paradigm Change', Energy Policy, 34, pp.3041-3048.

39. Ibid.

modify their equipment to improve their performance.

The most extreme manifestation of user innovation is, of course, open-source software, in which "users can create, produce, diffuse, provide user field support for, update, and use complex products by and for themselves in the context of user innovation communities."[40]

In a heavily regulated market such as energy, the challenges for this model are considerable. Fixed roles for the producer, supplier and consumer are embedded in the regulatory system, which can be very hard to subvert. For example, someone with solar panels on their roof has made the shift from a consumer to a producer of electricity. But they will find it extremely hard to sell their surplus electricity to the grid. Their supplier is not obliged to buy power back, and if it does, the rate is likely to be very low. They will also have problems connecting to the electricity distribution system, as network operators are not incentivised to connect small-scale power. In such circumstances, the green shoots of user innovation are in constant danger of being crushed.

With changes to the policy regime, though, it is possible to envisage much greater user-centred innovation for climate change. One nascent example is the Carbon Rationing Action Group (CRAG). A CRAG is a group of people who have decided to act together to reduce their individual and collective carbon footprints, through setting themselves an annual emissions target, which can be traded between members. CRAGs pride themselves on finding new ways to reduce emissions, through combinations of different technologies, services and approaches.[41] Their activities are being followed closely by the energy companies, who see a potential market opportunity in providing energy services along similar lines.[42] As energy provision is further decentralised, and as people are asked to play a greater part in reducing carbon, a more wholesale shift toward user-centred innovation could follow.

2.3 Break open closed systems

Following the twists and turns in the plotline of *EastEnders* is an important part of the working day at the National Grid's electricity control centre. So many people watched the 'Who shot Phil Mitchell?' episode in 2001 that electricity demand peaked to near-record levels. The control centre had to make sure that there was enough power to keep the grid going. Our demand for electricity is 'spiky' – it peaks at certain times of day. This means that we need to keep extra generating capacity to cope with increased demand. But it is very inefficient to keep power stations going just to deal with these spikes – and it's costly, in both money and carbon.[43]

Joe Short has a solution. One of the founders of Dynamic Demand, he is promoting a simple technology that could even out the spikes. From every plug socket in Britain, we can measure the health of the national grid. The hum of mains power sounds like a very low G on the piano, and goes up and down slightly depending on how much power is being used. Dynamic Demand control technology could be fitted to appliances like fridges and air conditioners, and turn them on and off in cycles. The device would cost less than £5 and would fit into a matchbox. It would allow your fridge to tune into the grid, and adjust its on-off cycle slightly so that it switched off when demand is high, and on when demand is low. You wouldn't even know it was happening, and it wouldn't affect the way the fridge works. But if enough appliances were fitted with the technology, the overall effect would be to smooth out demand and reduce the need for extra power generation. The technology could also be used to allow more intermittent renewable energy whose output fluctuates (like wind and solar power) than is currently possible.

Dynamic Demand is non-profit, but as a social enterprise it has huge potential. Last year, an independent report, commissioned by the UK Government, said that the technology provides a vital 'balancing' service, which could increase the cost-effectiveness of the grid considerably, as well as delivering carbon savings.[44] But the reality is sobering. Although Dynamic Demand could cut costs and carbon, there is no way into the market. In theory, the technology could earn money from the services it provides to power system operators, but in practice there is no way of releasing this potential. The way that the electricity market functions, and is regulated, prevents new entrants like Dynamic Demand from offering a profitable service. They are locked out of the system, because they offer a new solution that wasn't available when the regulations were developed.

Joe Short is an engineer by training, but he's beginning to realise that he needs to spend as much time lobbying as engineering. With the

40. Von Hippel, E. (2005), Democratising Innovation, (MIT Press, Cambridge, Massachusetts).

41. For more details of CRAGs see www.carbonrationing.org.uk

42. See, for example, British Gas New Energy, 'launched in April 2007 to offer green, low-carbon products and services to customers who want to manage their impact on climate change', www.centrica.co.uk/index.asp?pageid=1074

43. For more details on the grid and demand issues, see www.nationalgrid.com

44. Department for Environment, Food and Rural Affairs (2006), Market Transformation Programme Briefing Note BNXS41: Dynamic Demand Control of Domestic Appliances, (Defra, London).

help of some campaigner friends, he extracted a promise from Government to tackle the barriers to the introduction of the technology, as part of the 2006 Climate Change and Sustainable Energy Bill in Parliament.

2.3.1 Lock-in is not just economic

As Stern acknowledges, though, lock-in is organisational, social and institutional as well as economic – particularly in highly regulated sectors like energy or buildings. Established technologies will tend to set the performance standards and market structures in such a way that more innovative alternatives find it hard to break through.[45]

This is why Dynamic Demand finds itself in a situation where it struggles to win out, even though its effectiveness (and, in theory, profitability) is not in question. The way the electricity market is currently configured, it is hard to see who would pay for the technology. Consumers have no incentive, because they pay a flat rate for a unit of electricity – they don't pay more when demand is higher. Appliance manufacturers, who could easily and cheaply fit the technology, have no reason to, either. National Grid would benefit from dynamic demand technology, but has no way of asking thousands or millions of appliance owners to fit it. Until something is done to change the system, Dynamic Demand is a useful idea with nowhere to go.

While all innovations face challenges finding their place in an economy, the situation is probably more acute for low-carbon innovations, because we are so locked into fossil fuel-based energy and transportation systems.[46] Our economy, infrastructure and governance system have co-evolved over a long period of time, and reinforce each other. Given that carbon control is a more recent concern, the system has no means of accounting for carbon, or rewarding carbon saving. When gas and electricity were privatised in the 1980s, the overriding aims were to liberalise markets and bring prices down. This was before the Rio Summit or the Kyoto Protocol, so understandably the system that was established did not consider climate change. The new, privatised industries had little incentive for innovation or carbon reduction. So when something comes along that is both innovative and low-carbon, the system finds it hard to cope.[47]

2.3.2 Round pegs for square holes

Andrew Mercer of 2OC also knows all about lock-in – or lock-out, in his case. A serial entrepreneur, his growing interest in green issues made him keen to find a new low-carbon business venture. Andrew runs Footdown, a coaching organisation for entrepreneurs. One day, another Footdown member told Andrew about a carbon-free way of generating electricity – geo-pressure – being pioneered in Switzerland.

Geo-pressure electricity generation exploits the naturally-occurring pressure from the ground. Whereas geo-thermal technology has been known about for some time, geo-pressure is less well-used. But it can be exploited with the help of some existing infrastructure: the natural gas distribution system. Natural gas emerges from the ground under intense pressure and this pressure helps to drive the gas through the distribution network. Before gas can be safely distributed to consumers, the pressure is reduced at pressure reduction stations (PRS) throughout the grid. At the moment, when the pressure is reduced, energy is wasted. A small turbine fitted into the pipeline at a pressure reduction station can turn this wasted pressure into useable electricity, much the same way as a wind turbine works.[48]

Andrew saw the potential of exporting this model to the UK. Rough calculations showed that they could generate a lot of carbon-free electricity, and make a profit. If geo-pressure were fully exploited, it would add one gigawatt of capacity to the UK's network, saving one million tonnes of carbon per year – equivalent to the amount of carbon emitted by the entire National Health Service.

But it soon became apparent that it was much more difficult, and expensive, than they had realised. Geo-pressure generation involves a large number of small sites, yet the electricity transmission and distribution system is geared up to cope with a small number of large sites – large gas, coal or nuclear power plants.[49] Costs and difficulties involved in hooking up to the National Grid are considerable, because it is not geared up for distributed generation like geo-pressure. 2OC, like Dynamic Demand, suffers because it does not fit properly within the current infrastructure or institutions of our energy system. Andrew reviewed his business plan, and realised he could not compete with the cheapest forms of electricity generation – such as gas-fired generation, though costs were favourable compared to wind power, nuclear and other more expensive generation technologies.

45. Mitchell, C., and Woodman, B. (2004), The Burning Question: Is the UK on Course for a Low-Carbon Economy?, (IPPR, London), pp.63-4.

46. Unruh, G. C. (2002), 'Escaping Carbon Lock-in', Energy Policy, 30 (4), pp.317-325.

47. For more discussion of energy market issues, see p.26, Willis, R. (2006), Grid 2.0: The Next Generation, (Green Alliance, London).

48. For a more detailed explanation of geo-pressure, see www.2OC.co.uk

So 2OC turned to Government. At the time, the Government was reviewing its policy on climate change, and had just admitted that it had a 'gap' of around 10 million tonnes of carbon savings – it just didn't know how it would reach its target.[50] 2OC were offering a way of saving an extra million tonnes – as Andrew thought, there would surely be ways in which the Government could help them, so they could help the Government achieve the target. But they were met with a series of brick walls.

Government officials agreed that it was a good idea, but couldn't find a way of helping out. As geo-pressure had been used elsewhere in Europe, it was classified as an 'existing technology', and so was ineligible for research and development funding from the Technology Programme (formerly administered by the DTI). Geo-pressure isn't about the efficient end-use of energy, and so could not benefit from funding or support schemes for energy efficiency. But both the DTI and Ofgem were reluctant to contemplate the idea that geo-pressure could be seen as renewable energy and therefore benefit from the Renewables Obligation, which provides a level of price support for wind power and other renewables. Investment banks like Fortis, which fund other renewables, wouldn't offer any capital, so Andrew and his colleagues had to keep using their own money. Despite offering clear, cost-effective carbon savings, they could not find anyone to help them. They just didn't fit the system. Andrew Mercer said that geo-pressure was "a round peg for square holes. The way the system is set up, the Government doesn't have the capacity to understand developments at the fringes."

It took a considerable amount of fighting, and time and money, to get geo-pressure recognised. Eventually they got a legal opinion that it was eligible for accreditation as a renewable technology, and could therefore benefit from the Renewables Obligation. This single decision made the business model viable, and two-and-a-half years on, the first geo-pressure station is about to be installed, through a joint venture with the National Grid and BOC.

2.3.3 Turning the key

We have a situation, then, in which the system is stacked against low-carbon innovation. It is very hard for a new player – particularly an innovation which functions differently – to make an impact, let alone make a profit. As 2OC's Andrew Mercer says, "there are too many things that need changing: government attitude; corporations thinking about impact on their licence; problems with hook-up to the National Grid…" Lock-in is a particular problem in the electricity sector, but similarly large amounts of investment have been sunk into embedded infrastructure, institutions and policy in transport, housing and other fields.[51]

This is not a healthy situation. Low barriers to entry are a prerequisite of an innovative society. If barriers are high, competition is limited and innovation is restricted.[52] In an area with the highest need for innovation, to overcome our dependence on carbon, it is essential to find ways to overcome lock-in and make the energy sector more open to new, experimental approaches.

2.4 Make unusual connections

Innovation rarely comes from expected places. Significant breakthroughs often happen when different perspectives are combined, and different worlds collide. We should expect low-carbon solutions to emerge from all parts of the economy, not just the environmental technologies sector or the energy market.

SolarStructure is a case in point. When we met the small team they were eating lunch in a sunny café on the eighth floor of the Physics building at Imperial College in South Kensington. The cloudless weather was a reminder of the huge potential of solar technologies. It is estimated that the solar photovoltaics industry was worth $15.6 billion in 2006 and will grow to $69.3 billion by 2016.[53] In spite of this, getting a solar product to market has been far from easy, and there are still no guarantees of success.

What has become SolarStructure started four or five years ago with two Imperial academics and two HP employees who wanted to manufacture solar cells. One of the academics, Massimo Mazzer, a photovoltaics expert at Imperial, and Nigel Foan, formerly of HP with a background in opto-electronic manufacturing and photonics, are still working together. They won a DTI Smart award to develop the highest performance solar cell available at the time. The original intention was to manufacture solar cells and spin it out as a business. "But the market wasn't ready for the solar cells, so we looked for an application for those cells. We came up with some concepts and some IP (intellectual property) that we are trying to get out in the market now," says Nigel.

49. 2OC suggests that there are over 2,000 potentially suitable PRSs in the UK; see www.2OC.co.uk

50. Department for Environment, Food and Rural Affairs (2004), Review of the UK; Climate Change Programme, (Defra, London).

51. Fagerberg, J. (2004), 'Innovation: A Guide to the Literature', in Fagerberg, J., Mowery, D. C., and Nelson, R. R. (eds.), The Oxford Handbook of Innovation, (OUP, Oxford), pp.13-14.

52. For example, it has been shown that the higher entry costs and lower degree of turnover in European markets compared to those in the US are an important part of the explanation for the differences in growth patterns between the two continents; see Nicolette, G., and Scarpetta, S. (2003), 'Regulation, Productivity and Growth: OECD Evidence', Economic Policy, 36, pp.9-32.

The team continued to expand and started to look seriously at how to integrate its technologies into building design. They spotted a potential gap in the market for generating electricity from the sun in skyscrapers. "Skyscrapers are essentially big greenhouses. We have a solution which can take out all the heat and generate electricity through what looks like a Venetian blind. In some cases it could generate all the electricity needs of the building," says Nigel.

In the last year, SolarStructure has been riding the ups and downs of the business as it develops through an incubation period with Imperial and two unsuccessful funding applications to the Carbon Trust. In fact, the Carbon Trust has yet to invest in any solar applications in spite of the potential size of the market. Despite these funding difficulties, SolarStructure hasn't given up. It has developed a working model of its Venetian-style blinds, and now needs a prototype at scale. Rather than looking to venture capital, which may come with strings attached, it is looking for a corporate partner. But the idea may finally be poised to take off. "We've gone through the final stages where we're getting investment from a larger international company, which is a strategic partner. We want to build a demonstrator – we've built something small, but we need to build something at scale and work with these companies to prove that it's deployable, and then we'll sell the company."

2.4.1 Mixing it up

SolarStructure has benefited from at least two forms of alliances. The first is between disciplines, where each person made a unique contribution to bringing the idea from the lab to the product stage. SolarStructure is not alone in its need for a diversity of skills. DIY KYOTO combines interaction design and electronics engineering. "Our mix of skills was very useful. We cover all the key areas," says Richard Woods. Robin Murray says of GREENhomes, "It's essential to combine all perspectives – the hard-headed business thinkers, designers, environmental scientists, activists and economists all contributed to the prototype."

This has implications for ownership of innovation and technologies. Sharing knowledge between members of a team should not be problematic or else we risk limiting innovation. Within SolarStructure, because the members of the innovating team came from companies, universities and elsewhere, working out the ownership of IP was a painstaking process that slowed down the process of commercialisation considerably.

In this case, SolarStructure didn't have many other options than to go through the university technology transfer system – something that became a bottleneck in the company's innovation process. According to a study published in April by the Kauffman Foundation, the technology transfer offices that have been set up in the US function as 'monopolistic gatekeepers' rather than gateways to the market.[54]

The second form of alliance is formed between businesses with different aims and experience. SolarStructure was never going to be the kind of company that would deploy blinds to the world's skyscrapers. It would focus on making the best blinds, and look to a strategic corporate partner to verify that its product was needed in the market, then be in a position to develop it. Like the open innovation model, small companies bring fresh ideas to the incumbents.[55]

Small companies can do things bigger companies cannot. 2OC created links with big engineering companies BOC and Cryostar, acting as a catalyst "because big corporates don't take risks." 2OC is pushing geo-pressure forward through a joint venture with National Grid. "This is in National Grid's interests but it never would have come from within the company – partly because they wouldn't think that way, and partly because their licence (for gas distribution) forbids it."

2.4.2 Connecting sectors

Plan Vivo is another example of the creative solutions that can flow from unusual alliances. Plan Vivo was founded by Richard Tipper, who is now director of the Edinburgh Centre for Carbon Management. An economist and environmental scientist by training, he worked for years on understanding the impacts of forestry and land use. His research for Plan Vivo started in 1993 with an initial feasibility study funded by the Mexican Government. A full research programme got underway in 1996. But it was an unexpected lunch with Formula One supremo Max Mosley that really got things moving. Mosley was impressed by Richard's plans, and agreed that Formula One would purchase some carbon offsets. "This was a real breakthrough," says Richard. "At that stage, very few projects had actually started selling carbon."

53. This figure includes modules, system components, and installation, see www.cleanedge.com/reports-trends2007.php

54. Litan, R. E., Mitchell, L., and Reedy, E. J. (2007), Commercializing University Innovations: Alternative Approaches, working paper, (National Bureau of Economic Research, Cambridge MA). The report suggested a range of options, including the 'faculty loyalty' approach, where no intellectual property rights would be retained by the university. A version of this approach is now being applied at Manchester University.

55. See Chesbrough, H. (2003), Open Innovation, (Harvard Business School Press, Boston, MA).

Plan Vivo is about what works for farmers in developing countries. It's up to the individual communities and farmers to make their own plan for reducing carbon. Instead of being passive recipients of international aid, says Richard, "the farmers in the cooperatives came and said to me 'it would be a lot better if we could have what we needed. We should think about where we should plant trees and how it fits in with agriculture.'" The model is easily scalable, as it consists of simple contracts that allow people to work together to create plans and bring in their neighbours. Over 3,000 communities now contribute to Scolel Te. Plan Vivo has projects in Mozambique and plans for Nigeria. Richard is raising capital to start more Plan Vivo projects worldwide.

Plan Vivo is one small player in a burgeoning carbon market, linking directly or indirectly to a whole range of other initiatives that focus on trading carbon. The carbon market shows what can happen when a number of innovations link up together. Companies like Climate Change Capital help companies invest in projects for reducing carbon. These allowances can be bought and sold through the European Emissions Trading Scheme (EU ETS), itself an innovative piece of legislation which allows firms and nations to trade carbon in order to meet Kyoto commitments. Point Carbon provides analysis and consulting services for carbon markets. Consumer-focussed companies like Climate Care offer individuals the chance to offset their carbon emissions, by buying credits from organisations like Plan Vivo. The Co-operative Insurance Society will even offset some of the carbon emissions from your car, if you buy its insurance. Ten years on from Plan Vivo's first sale, these companies are all linking together to create a carbon market which traded 1.6 billion tonnes of carbon dioxide equivalent (CO_2e) in 2006.[56] This is equivalent to around three times the UK's total emissions.

Like any young market, carbon trading causes much controversy. There is a lively debate about the efficacy of offsetting, and particularly the role of tree planting in sequestering carbon emissions. A great deal of uncertainty surrounds the science of the carbon cycle, and it is undoubtedly too simplistic to equate a certain number of trees with a defined level of carbon saving.[57] The UK Government is currently drawing up standards for offsetting schemes, and the former Secretary of State for the Environment David Miliband has said that offsetting "isn't the answer to climate change", but has a role because "some emissions can't or won't be avoided."[58]

In addition, the process of emissions verification and compliance established by Kyoto's Clean Development Mechanism is complex and restrictive,[59] so many offset products, including Plan Vivo, remain outside, in the voluntary offsets market. But this allows for greater experimentation, and spaces where the range of possible projects, investors and buyers is expanded. "What we've tried to do with Plan Vivo is create a system outside the regulated carbon markets but supported by the voluntary sector, by those companies who understand that it's still experimental, and that we are developing processes that really work for communities in developing countries."

Despite the controversies surrounding offsetting, the emerging carbon market shows what can happen when separate innovations come together and collectively create value

2.4.3 Thinking like slime mould

Stephen Johnson's book *Emergence* begins with a story about slime mould, an incredibly simple creature that miraculously can find the shortest route through a maze when it wants to reach the food on the other side.[60] It transpires that a slime mould "spends its life as thousands of distinct, single-celled units, each moving separately from other comrades. Under the right conditions, those myriad cells will coalesce into a single larger organism" which then can move together to find food. "The slime mould oscillates between being a single creature and a swarm."

The tendency is to think of each innovation – whether it be a technology, product or service – as distinct from each other and their social contexts. But we also need to think about how innovations may link together synergistically, like slime mould, with lots of seemingly unrelated activities beginning to reinforce one another in a positive feedback loop.

Real progress is made when a series of innovations link together often in unpredictable ways, setting off a chain reaction of change. If the carbon market proves a disruptive part in a systems change story, it will be because it provides the impetus for clusters of social and technological innovations to converge on carbon reduction solutions, and simultaneously drive changes in how we manage those systems.

Each of the Disrupters could make a real difference to the way we control carbon. But when you put them together, the potential is far greater. In the household sector, a

56. Point Carbon (2007), Carbon 2007 - A New Climate for Carbon Trading, www.pointcarbon.com

57. See, for example, Transnational Institute (2007), The Carbon Neutral Myth, (Transnational Institute, Amsterdam).

58. BBC (2007), 'UK to Tackle Bogus Carbon Schemes', www.news.bbc.co.uk, 18th January.

59. For example, the Clean Development Mechanism (CDM), which allows carbon trading between developed and developing countries under the Kyoto Protocol, has only one approved land use project. The vast majority of these CDM projects involve methane capture, hydrochlorofluorocarbon (HFC) destruction, and large-scale efficiency in steel mills and coal mines, but provide funding for a relatively small number of renewable energy projects.

60. Johnson, S. (2004), Emergence: The Connected Lives of Ants, Brains, Cities and Software, (Simon and Schuster, London).

GREENhomes carbon package could include a Wattson, which would motivate people to keep on thinking about the way they use energy long after the auditors are gone. Add in the possibility of Plan Vivo offsets, and you begin to include more people in trading carbon. Within the power sector, the switch to more distributed forms of generation needed to get 2OC's geo-pressure technology off the ground would need a more responsive, two-way national grid. Dynamic Demand could be an important component of achieving this responsiveness. Barnsley, having led the way in biomass renewables, could provide a testing ground for other innovations, too. The Disrupters clearly demonstrate the possibilities of thinking in terms of clusters of innovations, and to create policy that supports this.

Part III: From the margins to the mainstream

3.1 Learning from the Disrupters

What do the experiences of our Disrupters teach us about the prospects for low-carbon innovation in the UK?

First, that innovative, entrepreneurial efforts to tackle climate change are proliferating. Not just new technologies for energy generation, but new ways of owning energy assets; new services that engage people in energy saving; and new business models that open markets up to new entrants. Not just in the private sector, but across the public sector and community groups too. Motivated both by a commitment to the issue and a desire to make a business opportunity out of a necessity, the Disrupters offer new ways to address one of the biggest challenges we face.

Table 1: Estimated carbon reduction potential of the Disrupters

Disrupter	Estimated impact	Savings t/CO_2 per year[61]	Potential for scaling up (approx five years)	Total potential savings each year t/CO_2
Barnsley Metropolitan Council	Estimated savings: 2320 t/CO_2 per year[62]	2,320	Assume 100 local authorities in the UK made similar investments	232,000
DIY KYOTO's Wattson	First year sales of the Wattson could reach 10,000, with a saving of 328 kg/CO_2 per home[63]	3,280	Assume one million are sold over the next five years.	328,000
GREENhomes	1 tonne CO_2 per home per year, 5,000 homes this year[64]	5,000	One million homes	1,000,000
Baywind	Yearly average avoided emissions: 6,768 tCO_2/year[65]	6,768	Assume 100 local communities in the UK made similar investments	676,800
Dynamic Demand	Estimate of savings: 0.6 mtc per year[66]	2,100,000	N/A - Applied to the entire electricity grid	2,100,000
2OC	Estimated savings: 1 million tonnes of carbon[67]	3,700,000	N/A - Applied to the entire gas distribution network 3,700,000	3,700,000
SolarStructure Limited	Estimated savings from one 12,000 sq meter building (such as London City Hall)	748[68]	Assume we apply the product to 1,000 buildings throughout the UK[69]	748,000
Plan Vivo	Plan Vivo's Scolel Te project[70]	30,000	100 'Plan Vivo' communities around the world	300,000
	TOTALS	**5,847,679**		**9,084,800**

61. All measurements are in estimated tonnes of CO_2e. 1 metric tonne of carbon = 3.67 tonnes of CO_2e. To obtain kg CO_2e from electricity output in kWh, divide delivered electricity figures by 0.43, and primary electricity by 0.1661. See the Carbon Trust (2006), Energy and Carbon Fact Sheet, (Carbon Trust, London).

62. Figures from the Ashden Awards website, at www.ashdenawards.org/technical_summary06_UK_barnsley_biomass

63. DIY KYOTO estimates the potential at up to 20 per cent. More conservative studies have shown that installing smart meters can reduce energy use by 3-15 per cent. See energywatch (2005), Get Smart: Bringing Meters into the 21st Century, (energywatch, London).

64. See www.greenhomeslondon.co.uk

65. Figures available on Baywind's website – Harlock Hill plus one quarter of Haverigg II, which Baywind also owns. See www.baywind.co.uk/production.php

66. 0.6 mtc is equivalent to 2.1 million t/CO_2, according to research by Dynamic Demand, see www.dynamicdemand.co.uk/pdf_co2.pdf

67. 2OC figures available on its website, www.2OC.co.uk/. For every tonne of carbon generated, 3.7 tonnes of CO_2 is emitted.

68. One m^2 uses 145kwh/year. This figure comes from the US Energy Commercial Buildings Energy Consumption Survey (www.eia.doe.gov/emeu/cbecs/contents.html) which SolarStructure used to calculate their potential savings. Between 50 and 100 per cent of daily energy use can be saved, according to SolarStructure interview, depending on the building's efficiency and façade area to floor area ratio.

69. Retrofitting 12 million m^2 of office space is not unrealistic. London alone has 110 million square meters of commercial floor-space and further development of 16.4 million square meters is expected; see p. 27, Greater London Authority (2007), Evidence Base: Climate Change in the Further Alterations to the London Plan, (GLA, London).

70. This project involves 3,000 people and 5,000 hectares saves an average of 25,000 - 50,000 tonnes of CO_2 year.

Second, that even though the Disrupters are small, their overall impact could be significant. It is difficult to measure what the overall contribution of these innovations could be, in terms of direct carbon savings. In the table below, we estimate what the savings could be if the Disrupters grew and prospered over the next five years. The total amount of carbon dioxide saved could be around nine million tonnes per year – this is equivalent to the carbon dioxide emitted by 1.6 million homes.[71] But the Disrupters and others like them could also have a wider effect, if their innovations are adopted by bigger players, if they put other companies under pressure to change, or if they persuade more people to take wider action on climate change.

Third, we need to find better ways to support innovators like the Disrupters, to allow them to fulfil their potential. All the Disrupters did receive direct support – either in the form of grants from central or local government, or, in the case of 2OC and Baywind, help from the Renewables Obligation. Financial support of this kind is a help, but is not a substitute for a broader system which encourages and enables low-carbon innovation. 2OC may have support from the Renewables Obligation, but they have encountered serious obstacles in the way that the national grid for electricity is regulated and managed. SolarStructure received innovation funding, but there is still a limited market for their product, because energy policy has concentrated on supporting large generators who ship cheap power down the wires, not on-site generation in buildings, which SolarStructure enables. Innovations aimed at individuals, like GREENhomes and the Wattson, are hampered because there has been no obligation and little encouragement for individuals to save energy at home.

The experience of the Disrupters points to the need to rethink the way that we manage both climate change policy and innovation policy, encouraging greater linkage between the two, and creating a policy framework that enables innovation.

71. According to Best Foot Forward, each home produces on average 5.595 tonnes of carbon dioxide; Best Foot Forward (2006), Domestic Carbon Dioxide Emissions for Selected Cities, (Best Foot Forward, Oxford).

3.2 Inviting innovation

Reducing the UK's climate change impacts is an important objective for government. But as we described in Part 1, policies to support innovation have, so far, been poorly aligned with climate change objectives. How, then, can government support the Disrupters, and other innovators who are working to move the UK onto a low-carbon path? In summary:

- First, **government should see itself as an enabler.** The government has committed itself to year-on-year emissions reductions, on a clear pathway to a low-carbon economy. This needs to be supported by an enabling policy framework which sets an equally clear goal, and within which low-carbon innovation can flourish. A low-carbon 'Innovation Platform' could be the first step to achieving this;

- Second, **government should find new ways to talk to low-carbon innovators and entrepreneurs**, as an alternative to well-established companies and trade bodies;

- Third, government needs to **create spaces for experimentation**, to help innovations which are 'locked out' of current systems. We propose creating a number of low-carbon innovation zones, which combine different forms of technological, service, behavioural and organizational innovation in creative ways;

- Fourth, government needs to **rethink the way that it funds innovation**, and redirect some investment towards lower-carbon alternatives, including support for non-technological innovations, such as behaviour change;

- Fifth, **energy markets should be reformed to create better incentives for innovation**. This could be achieved through streamlining responsibility for energy and climate change, and changing the remit of Ofgem to allow it to create better incentives for innovation.

3.2.1 Government as enabler

The Climate Change Bill, currently before Parliament, presents a clear set of targets for the UK to reduce carbon emissions year on year. This needs to be supported by an equally clear policy framework. Government must provide a stable and supportive environment for low-carbon innovation. This sounds straightforward, but is complex in practice. It would require far stronger linkages between energy policy and innovation policy, and a more active management of energy markets – both of which challenge the policy *status quo*.

The Dutch model of 'transition management' is a good example of a concerted attempt by government to act as an enabler of low-

carbon innovation. Their Energy Transition Programme takes a long-term view of the outcomes needed; adopts a system-wide perspective, within which individual technologies and approaches are situated; works with government, society and business to set policy aims; and brokers networks and coalitions between the different actors involved.[72] The Dutch model could not be transplanted wholesale to the UK, as it is quite specific to the consensual political culture of the Netherlands. It has also been criticised in some quarters for overemphasising process at the expense of politics.[73] But as a strategic approach it still has many merits and the UK government should take the opportunity presented by the passage of the Climate Change Bill to explore what a transition management strategy for the UK would look like.

A starting point for such an approach could be the creation of a low-carbon Innovation Platform. Introduced in 2005 by the Technology Strategy Board (TSB), Innovation Platforms bring stakeholders together to focus on a societal challenge, enabling "the integration of a range of technologies and better coordination of policy and procurement, resulting in a step change in UK performance."[74] A new low-carbon Platform (particularly given the new, expanded remit of the TSB) could become the focal point for practical efforts to integrate innovation policy with energy and climate change policy, in line with the ambitious targets laid down in the Climate Change Bill.

3.2.2 New ways of talking to innovators and entrepreneurs

Government has no obvious channels of communication with the Disrupters profiled here. Major trade associations tend to represent the interests of incumbents, and often lobby against environmental policy measures that could support innovators and new entrants.[75] Specific trade bodies for the environmental sector, such as the Environmental Industries Commission, do lobby for more intelligent regulation, but the sector they represent is very specific, relating to environmental technology and services, rather than broader (and often non-technological) forms of low-carbon innovation. And among larger companies, even those that take a lead on climate change may simultaneously resist policy changes that they perceive as going against their company's short-term interest.[76]

When individual companies do find a way to talk to government, it pays dividends. 2OC worked with officials from the then DTI and Ofgem to clarify the position of geo-pressure, and the outcome was geo-pressure's inclusion in the Renewables Obligation, providing the price support that makes their business model work. Similarly, Dynamic Demand benefited from expert lobbyists who knew how to get their ideas into parliamentary discussions.

However, both these companies were unusual in having the contacts necessary to approach policymakers directly. Many more do not know where to begin, and government could be far more proactive in seeking out and listening to fledgling low-carbon businesses:

- Through working with recipients of government funding and support, including the Technology Programme (formerly administered by the DTI), the Carbon Trust's research funds and incubator programmes, the Low Carbon Buildings Programme and other grants administered by the Energy Saving Trust. Grant recipients should be asked about how government has helped or hindered their project, and consulted on potential future changes;

- Through seeking the help of third parties in reaching out and talking to entrepreneurs – such as Cambridge's Centre for Entrepreneurial Learning. Such dialogue should not be seen as formal consultation, but as a chance for government to better understand the motivations and needs of low-carbon innovators;

- Through joining in and supporting the activities that are already taking place, in a growing number of social and environmental entrepreneur networks and meet-ups. For example, the Birkenhead Forum,[77] which holds monthly events for those active in the social and environmental investment sectors and the Sustainable Technology Group,[78] which organises meetings in London through Meetup.com.

3.2.3 Spaces for experimentation

As the Disrupters show, it is difficult to be a low-carbon innovator when markets, regulations and policies are set up to support high-carbon incumbents. These barriers need to be dismantled through system-level interventions, rather than individual policy or funding mechanisms. But introducing such system-level change is often politically risky and practically difficult.

72. Foxon, T., and Pearson, P. (2007), 'Overcoming Barriers to Innovation and Diffusion of Cleaner Technologies: Some Features of a Sustainable Innovation Policy Regime', Journal of Cleaner Production, forthcoming; see also www.energietransitie.nl

73. Smith, A., and Stirling, A. (2006), Moving Inside or Outside? Positioning the Governance of Sociotechnical Systems, SPRU Electronic Working Paper Series paper no. 148, (SPRU, University of Sussex, Falmer).

74. See www.dti.gov.uk/innovation/technologystrategy/innovation_platforms/index.html

75. Caulkin, S., and Collins, J., (2003), The Private Life of Public Affairs, (Green Alliance, London).

76. Ibid.

77. See www.gexsi.org/birkenhead_forum.htm

78. See http://environment.meetup.com/302/?gj=sj5

One way forward would be to designate a number of low-carbon innovation zones across the UK. These would not be traditional Silicon Valley-type innovation clusters based around producers, but would focus on demand as well as supply. Local and regional decision-makers could pledge ambitious carbon cuts, and set a framework to achieve them. In return, they would be given greater autonomy and scope for regulatory experimentation, and a larger share of funding, to find ways to involve local households, communities, businesses and the public sector in carbon reduction. In effect, these zones would act as test-beds for low-carbon devolution.

Each area could put together its own package for achieving carbon cuts, including measures such as:

- Encouraging or mandating renewable energy through planning policy, as Merton Borough Council has done;
- Offering Council Tax reductions in return for home energy efficiency measures, as pioneered by Braintree Council;
- Upgrading electricity distribution networks to allow more distributed generation to connect;
- Offering smart meters to householders, and requiring electricity suppliers to charge according to the time of day;
- Acting as a pilot area for technologies like Dynamic Demand or the Wattson;
- Establishing a voluntary local carbon trading scheme, with incentives for participation;
- Involving local communities in deliberative dialogue about solutions to climate change, and linking this to incentives for action.

These low-carbon innovation zones could tie into existing initiatives, starting with towns or areas that have already identified themselves as low-carbon leaders. There are plenty of possibilities.

Like Barnsley, Woking Borough Council is experimenting with new approaches to energy, and is now almost entirely self-sufficient. It has cut carbon emissions by 77 per cent over 15 years, thanks to a private grid system powered by renewable generation.[79] Ashton Hayes, a village in Cheshire, has pledged to become the UK's first carbon neutral community. London's new Climate Change Agency is creating Energy Action Areas to pioneer new approaches. Other initiatives are community-generated – such as the Transition Towns initiative, a Wiki which aims to be a "focal point for all towns, villages, cities and localities around the world that are self-organising for an energy lean future."[80] Such initiatives are potential stepping-stones towards low-carbon innovation zones. However, all these initiatives are working within the restrictions of existing policy and regulation. Establishing low-carbon innovation zones could enable such areas to experiment with new approaches to policy and regulation, too. Areas could be asked to bid for such status to be conferred, competing for funding and the right to experiment. Successful experiments could then be evaluated and considered by national governments for adoption more generally.

79. Greenpeace (2005), Decentralising Power: An Energy Revolution for the 21st Century, (Greenpeace, London).

80. See www.transitiontowns.org

3.2.4 More flexible funding mechanisms

Grant funding alone can never become an effective substitute for clear policies and a regulatory system that rewards innovation. But carefully-targeted funding can help innovators to gain a foothold.

At present, funding for low-carbon innovation, such as the Technology Programme and the Carbon Trust's innovation funds, tends to be heavily technology-focused. Some non-technological innovations may therefore lose out, even if their ideas could result in considerable carbon savings.

In addition, a significant amount of government innovation funding is offered to businesses without consideration of the carbon implications. The support aimed specifically at low-carbon innovation risks being swamped by more general innovation support, with uncertain or negative carbon impacts.

The following changes could be made to the funding regime: Government should carry out a carbon audit of its innovation funding streams, and consider how funds could be shifted toward low-carbon innovation, in line with the Stern Review recommendation that incentives for low-carbon technologies should increase two to five times.[81]

- There should be flexible funding available for non-technological innovation, like GREENhomes or Baywind; or for companies working with existing technologies which have not yet been deployed successfully in this country, like Barnsley's biomass or 2OC's geo-pressure. The funding should help with

the costs of developing and trialling new business models;

- The Department for Business, Enterprise and Regulatory Reform (DBERR), the Department for Innovation, Universities and Skills (DIUS), and the Office of the Third Sector in the Cabinet Office should instigate a joint review of how low-carbon entrepreneurs and innovators can be encouraged and supported.

3.2.5 An innovative energy market

Lastly, there is an urgent need to encourage investment and innovation in energy markets, and to provide better incentives for small-scale generation, and energy saving. This would help innovations like Barnsley's biomass, Baywind and GREENhomes, who are trying to derive a profit from small-scale energy and energy saving services. It could be done in two ways:

- There should be greater strategic coherence between energy supply and energy demand issues. At present, supply-side policies aim to reduce the unit cost of electricity; demand-side policies ask people to value and conserve power. The more we can link supply of energy to demand for energy, the more likely we are to find ways of using it well. The creation of the new department DBERR, with responsibility for energy, offers an opportunity to reconsider how to link supply-side and demand-side policies for energy;

- The mandate and duties of Ofgem should be reconsidered. Rather than being focussed around narrow consumer protection issues, its objectives should be broadened to include specific references to reducing emissions and encouraging low-carbon innovation. There are many ways that Ofgem could promote innovation, including prioritising investment in electricity networks to accommodate greater distributed generation; encouraging smart metering and time-of-day pricing for electricity; and opening markets to a wider variety of players.[82]

The UK has made clear its commitment to tackling climate change. It has led the international debate on how to achieve the deep cuts in emissions that are required. And the Government's commitment to innovation more generally is impressive: with the right forms of support, organisations large and small will continue to strengthen the innovative capacity of our economy. However, to date, these two powerful forces have not always pulled in the same direction. If they can be properly aligned, the potential is enormous. The Disrupters offer us a glimpse of a future that we can still seize: carbon-constrained, certainly, but with no restrictions on innovation. And it is this innovation, in all its diverse forms, which will determine our success or failure in moving onto a more sustainable path.

81. p.347, HM Treasury/Cabinet Office (2007), Stern Review on the Economics of Climate Change, (HM Treasury, London).

82. Sustainable Development Commission (2007), Ofgem: Looking Back, Looking Ahead, Opinion Piece, (SDC, London), and Willis, R. (2006), Grid 2.0: The Next Generation, (Green Alliance, London).

Appendix: The Disrupters

Name	**Barnsley Metropolitan Borough Council**
Location	South Yorkshire, England
Sector	Alternative energy
Employees	One employee working specifically on biomass
Date started	2004
Funding	Barnsley Council, CEP, Yorkshire Forward, the Bio-Energy Capital Grant, and the 2006 Ashden Award.
Business model	Biomass heat, and energy services
Impact	Before the project, Barnsley used 6,500 tonnes of coal per year (15,724 tonnes CO_2e). The Sheffield Road flats, Smithies Lane Depot and the new Westgate Civic Plaza provide an estimated savings of 2,320 tonnes of CO_2e per year.
The concept	To reduce emissions in Barnsley and revive an area hit by coal mine closures in the 1980s, Barnsley re-envisioned its coal infrastructure, and began refitting and rebuilding for biomass. An energy services company and a new biomass industry have sprung up to service the flats and municipal buildings where biomass is used.
Brief description	Barnsley's biomass comes in part from local municipal wood waste. Woodchips are transported weekly by a local business Silva Power, stored in a bunker just outside the buildings where they will be used, and then fed into the boilers automatically. An energy management system monitors how much heat is needed, and the boilers adjust their output accordingly. An energy services company, Econergy Ltd, manages the boiler and heating systems. Silva Power sells woodchip at £35 per tonne, and Econergy sells heat to Barnsley Council. Tenants in the Sheffield Road block of flats pay up front for heat on smart cards, where before they paid a flat rate as part of their rent.
Progress to date	**June 2004:** Inspired by a trip to Austria and Switzerland, where woodchip and wood pellet boilers are commonplace, Richard Bradford, Principal Designer and Energy Manager for Barnsley Council, decided to try switching from coal to biomass boilers.

Richard wrote a biomass policy to take to the Council and simultaneously won funding from Yorkshire Forward to conduct a trial of wood pellet boilers in municipal buildings. Although it had never been done before, the Council trusted Richard's track record in building maintenance and design, and gave him the green light for biomass heating.

2005: The first project to open was a renovated social housing estate in Sheffield Road, where the coal boiler that had provided heat at flat rates was replaced with two woodchip boilers, providing heat and hot water to 166 flats on a metered basis. A local start-up Silva Power Ltd began supplying the site with woodchips made from local wood waste.

Early 2006: The second project, a 500kW Fröling wood chip boiler, was installed to provide heat and hot water to 450 council employees working at Smithies Lane Depot.

Late 2006: New buildings began to be built with biomass boilers. The first phase of the new Westgate Plaza One civic headquarters (home for many of Barnsley MBC offices) saw the installation of a 500kw boiler, which provides heat to the building during the day. At night, the same boiler is planned to heat a nearby library and the Town Hall.

Barriers encountered

None described. Richard has no complaints about the support for his project. Because (in the first cases) the coal infrastructure was in need of replacement anyway, he had no trouble selling new ideas to the Council and other partners.

Future plans

Barnsley's new Digital Media Centre, a flagship development for the regeneration of the town, will be biomass-heated.

Richard is advising other councils on how they too can switch to biomass.

Website

www.barnsley.gov.uk

Name	**DIY KYOTO**
Location	Bethnal Green, London
Sector	Consumer electronics
Employees	Seven
Date started	September 2004
Funding	£35,000 from NESTA Creative Pioneer Programme; six-figure additional funding from private investors.
Business model	Product combined with online social networking.
Potential impact	Reducing household energy consumption through making energy use visible to the consumer could yield a 20 per cent change in use over the year.
The concept	DIY KYOTO aims to make environmental information interesting and engaging. Their first product, the Wattson, makes energy visible. "We don't want this to be seen as a green product that people feel like they should have, people should want to buy it. This is an aspirational product."
Brief description	The Wattson is a sleek device that measures the aggregate energy consumption of a household, and translates it into cost over the year. The Wattson glows red in high consumption times and blue when appliances are switched off. Designed by Richard Woods, Jon Sawdon Smith and Greta Corke, it has been written up in lifestyle magazines, newspapers and on environmental and technology blogs. The premier, handmade version of the Wattson is available for £350. The manufactured version can be pre-ordered for £125 on their website.
Progress to date	**September 2002:** Richard Woods was beginning his second year on an industrial design engineering MA course at the Royal College of Art when he became interested in energy, and carried out an energy audit of his home. He designed a device to measure how much power household appliances use when they are on, off or on standby. He worked out daily costs, and then estimated the costs over a year. At the end of the test, his estimates correlated pretty well to billed electricity costs. **2003**: Richard discovered that in 2000, another Royal College of Art graduate, Jon Sawdon Smith, had looked at a utility monitoring device. It was more complex – measuring every plug in the house, equipped with a modem and connected to a central computer which displayed the household usage. Jon had just returned from IDEO in San Francisco and decided to join Richard. Greta Corke, who specialised in interaction design at the Royal College of Art in 2000-2, was engaged in a project at the V&A making energy visible. She joined the team because she was interested in connecting her work to measuring energy. **February, 2005:** The three partners were able to go full time in February 2005 when they won £35,000 through the NESTA Creative Pioneer Programme. Richard worked on the business plan full time for 6 months, and the three designed the product together. **February 2006**: An article in the British Airways inflight magazine led to their first big investment, which came just as their NESTA funding was running low.

This is also when they started selling the Wattson, though they told people to expect a longer lead time. Even as the lead time grew, people did not cancel their orders. "They believed in what we were doing. We've had a lot of people say thank you, it's really making a difference."

Barriers encountered

The most difficult times were encountered in the design and proof of product stage. The second round of funding after the initial NESTA grant came just in time.

They have embarked on an alternative strategy to patenting. The radio technology behind the product is in the public domain. DIY KYOTO could not afford the cost of obtaining or defending a worldwide patent, so instead they are focused on the unique design and brand.

Future plans

Going forward, smart metering requirements should help their business because people will have much more control and awareness of their energy use.

Because the Wattson has a USB port, energy use data can be uploaded to a central website, where DIY KYOTO's online social networking tool will show cumulative energy use and carbon emissions from all Wattson owners. The Wattson's feedback could become part of buying decisions, allowing people to make changes in their own lives, and combined with online social networking, to see their own behaviour as part of something bigger. "You get to talk to people, share ideas, compare yourself to a family in Japan. Feedback is key to our way of thinking."

DIY KYOTO may be early movers, but they are not alone. "We know people are now thinking about this seriously and they will wait to see if the market is proven before they come in. We are doing the legwork to prove there's a market."

Website

www.diykyoto.com

Name	**GREENhomes**
Location	London, England
Sector	Energy and household audit, consulting and services
Employees	Ten
Date started	2006
Funding	Supporting organisations include the Greater London Authority, Defra, London Climate Change Agency, London Development Agency, London Energy Partnership, The Design Council, The Energy Saving Trust, who backed the design phase and chair the Steering Group, and The London Borough of Lewisham, where the service prototype is taking place.
Potential impact	GREENhomes aims to save an average of one tonne of CO_2 per household per year. Their target is to green 7,000 homes, saving 7,000 tonnes of CO_2 by the end of the first year.
Business model	Concierge services create an ongoing relationship with clients, providing needs-driven advice and introductions to service providers.
The concept	GREENhomes helps people reduce their energy use and carbon emissions. It was developed by Robin Murray of Ecologika and Andrew Long of Ten. Robin has worked for many years on how environmental issues could be tackled in the community. Andrew Long and his brother Alex Cheatle built a lifestyle concierge business and knowledge management system. What they have in common is a belief that a new kind of support economy will be required to tackle climate change, drawing on the enthusiasm and innovation of users and citizens.
Brief description	The GREENhomes service consists of an energy audit and services based on the audit's results. The first step is always to ask people where they think their home uses energy, and then to find out what they are most interested in achieving – from comfort to saving money to reducing CO_2. Once people know more about their energy use, Andrew hopes they will go and spread the word within their own networks. The project is now part of Ken Livingston's Climate Action Plan, which aims to reduce London's carbon emissions by 60 per cent by 2025. The ideas behind GREENhomes have been around for a long time. Only through new knowledge management tools, and a growing public awareness of climate change has the vision become possible. GREENhomes is currently finishing a prototype phase with 60 homes across London.
Progress to date	**Early 1990s:** Robin Murray spent some time in Ontario, Canada, where he was intrigued by the Green Communities programme, which was creating jobs as well as reducing carbon emissions at the local level. **1995-6:** He returned to the UK and toured a few communities to see if a Green Communities project would work in the UK, but decided the appetite for such a service was still low. **2004-5:** After a year in the Design Council working on how design could be applied to the health sector, Robin began looking again at how user-oriented design might influence behaviour around environment. He brought together

a coalition of environmentalists and designers with the idea of building a GREENhomes-like service. This design phase was called the Future Currents project, and involved experimenting with different energy audits on a house in Lewisham.

Robin met Alex Cheatle, CEO of Ten, at a conference and spotted a potential synergy in their ideas. Alex and Andrew had grown their business by delivering a consistently top quality service. All interactions with their clients and service providers are added to their proprietary database, making it possible to provide a highly personalised service at scale, and at low cost to the customer.

2006: Ecologika and Ten joined forces to design a prototype project in Lewisham. The aim is to learn from this and create a service that people are willing to pay for.

Barriers encountered

Planning can be a barrier. For example, Lewisham gives tax breaks for solar panels, but people in conservation areas are frustrated when they realise they cannot take advantage of them.

People's expectations need to be managed carefully. People have often heard of micro-renewables and call GREENhomes asking for them. But for many homes in London, installing insulation or a new boiler often provides more savings than flashier options like home wind turbines. In some of London's older buildings, it will be impossible to earn the coveted 'A' rating without huge expenditure. This can discourage homeowners from doing anything at all.

Future plans

A pilot phase aiming to reach 5,000 homes in London will start this year.

Andrew Long has found that people want to achieve CO_2 reductions not only in the home but in their daily choices around transport or leisure as well. He sees the potential for applying the green concierge service to all aspects of people's lives.

Name	**Baywind**
Location	Cumbria, England
Sector	Renewable wind energy
Employees	Three
Date started	1996
Funding and partners	A Swedish company, Vindkompaniet provided four of the six wind turbines. Baywind received £50k of funding from Co-op Mutual, to fund a development officer for Energy4All. Baywind has close links with the Co-operative Movement, who see renewable energy as a possible growth area for co-operatives.
Business model	Co-operative ownership of renewable electricity generation.
Potential impact	Baywind is a 2.5 MW wind farm, which will achieve approximately 4,200 tonnes of CO_2e savings per year.
The concept	Baywind provides an alternative model of renewable energy generation and a profitable ownership model. The Baywind model could lead to increased levels of renewable energy in the UK, and greater diversity of energy sources. Abroad, notably in Denmark and Germany, a high proportion of wind power is owned in this way.
Brief description	Baywind is a cooperative renewable energy company with five wind turbines at Harlock Hill. It has over 1,300 shareholders who are motivated by both the environmental and financial benefits. Baywind shares are rarely sold. The typical Baywind shareholder is a retired professional, living locally. Baywind is made possible because of the Renewables Obligation, and the (now-defunct) Non-Fossil-Fuel Obligation. Baywind energy costs 5p per unit (kWh) to produce, though this is likely to be an underestimate because its directors claim little or no remuneration. Electricity is sold for 8p per unit, providing a steady return to members. Many in the area see wind energy as an alternative to nuclear power: the turbines lie between the Heysham nuclear generator and the reprocessing facility at Sellafield. Richard was "at school in Barrow when one of the UK's worst nuclear accidents happened nearby, at Windscale." Richard's antipathy to nuclear power is shared by most Baywind members.
Progress to date	**1995-6:** Ulverston town council voted fourteen to one against the turbines. The only person who voted for the scheme was Richard Scott, who was then invited onto Baywind's board. **1996:** Planning permission was finally granted after a surprisingly difficult process. Despite being 'asked for cheques in return for little more than a promise', as Richard describes it, 600 people, many local, bought in, raising enough money to buy one turbine for £600,000. Vindkompaniet financed the other four turbines. **1997:** 300 shareholders attended the opening ceremony, and the first wind turbine started turning. Shareholders have enjoyed steady returns of around six percent a year, and will recoup their original stake at the end of the 20-year lifetime of the turbines.

1999: Another share offer was put out, allowing Baywind to raise enough money to buy a second turbine from Vindkompaniet.

2002: Energy4All was founded and began trading in 2003.

2004: Baywind won an Enterprising Solutions award from the DTI in recognition of its work.

2007: Baywind is now halfway through its twenty-year lifespan, is a profitable project, and boasts 1,350 members.

Recently, with Energy4All's help, £4.5 million was raised to buy eight turbines and establish the Westmill co-operative in Oxfordshire.

Barriers encountered

Local government planning processes were a major obstacle to Baywind, and in Richard's view, this problem remains, despite recent planning guidance (PPS22) which should encourage the development of renewable energy.

Government policy in the form of the Renewables Obligation has helped Baywind by providing a good price for its electricity. This is the only help they have received – they had no grants or other support. They do not qualify for grants that help smaller projects, such as the Community Renewables Fund or the Low Carbon Buildings Programme. Nor do they have the economies of scale enjoyed by larger wind farms.

Baywind may face difficulties in replicating its model, because it relies on the dedication of a small group of individuals, most of whom have other occupations as well.

Future plans

To spread the co-operative model of co-operative windfarms, through Energy4All, Baywind has created a network of groups who are in differing stages of getting wind farms up-and-running.

Energy4All gets many enquiries from enthusiasts for wind power, but very few enquiries translate into new projects. Baywind sees the need for a responsive, independent service to help communities meet their energy needs.

Name	**Dynamic Demand**
Location	London, England
Sector	Energy
Employees	One plus an active advisory board
Date started	Joe Short started to work full time in early 2005
Funding and support	Esmee Fairbarn Foundation funded Joe Short for two years to pursue the idea. The DTI has also recently agreed some additional support.
Potential impact	Dynamic Demand estimates savings from 0.6 to 2 million tonnes of CO_2 each year.
The concept	To reduce the energy used by appliances in our homes automatically by making them responsive to peaks and troughs in electricity demand. If introduced across the network, this could smooth out the spikes in demand for electricity, or supply from renewables, leading to huge efficiency and carbon savings, and reducing the number of power stations needed for reserve or back-up power.
Brief description	Dynamic Demand is a not-for-profit organization promoting and introducing demand management technologies for the UK grid. A dynamic demand device would be invisible to the consumer, hidden in appliances which turn off during periods of peak energy use. Tests so far have shown no negative impacts. The technology could be adopted on a widespread basis as appliances are replaced.
Progress to date	**2003:** At Loughbrough University's Centre for Renewable Energy Systems (CREST), Joe Short learned about spinning reserve, when extra power plants are kept on a kind of cruise control, ready to fill energy demand at peak times. He wondered if some of the energy spikes could be controlled on the demand side. The Dynamic Demand technology idea grew from that thought. Appliances today cannot 'listen' to the mains hum, the rate at which electricity is going in and out (the alternating current). At about 50hz per second, it sounds like a very low G on the piano. Joe's thesis explored the algorithm that would allow millions of appliances to respond at once. He knew he had hit upon a good idea when during his Masters thesis presentation, the room began to fill with people coming in to listen. Joe and an advisory group began to discuss the legislative implications of dynamic demand. **January 2005:** Esmee Fairbairn funded Dynamic Demand, allowing it to incorporate. Joe Short started to work on the project full time. **March 2006:** The birth of dynamic demand technology came when Simon Leach, senior scientist at Intertek, asked to do some laboratory tests as part of the Market Transformation programme at Defra. The proof-of-concept unit was a PC that sat outside a refrigerator, connected with wires and probes. Channel 4 News filmed the tests and interviewed them, producing a three-minute special report.

March was also the month when Lord Redesdale organised a crucial lunch, giving them the opportunity to meet everyone from Government officials to component and refrigerator manufacturers.

Dynamic demand was discussed in Parliament and written into a private bill.

June 2006: The Climate Change and Sustainable Energy Bill included a clause requiring the government to look at the potential for dynamic demand technologies.

September 2006: Liberal Democrats passed a motion that Ofgem should reform the rules governing electricity contracts.

Barriers encountered

Joe Short not only had to prove the technology, he first had to prove his idea. A milestone came when he and David Infield, head of CREST, gave a presentation at the National Grid control room in Wokingham. The engineers were focused on the 20 x 50 ft computer screen image of the UK, a circuit diagram with live updates. They had more to worry about than a refrigerator demonstration from Joe and David. But they warmed to the idea. When one engineer said, "Initially, I didn't think this was something we'd take seriously, but now I'm not so sure," this felt like high praise indeed.

Joe saw that no one organisation or stakeholder had enough interest to step in and support the idea. He overcame this potential barrier by taking a non-profit, open source approach to the IP behind the idea, thinking that this would be the fastest way to get everyone – regulators, manufacturers and utilities – on board. The strategy paid off. "When you take a not-for-profit route and you're honest about your intentions from the start, people just come out of the woodwork and help. Often the hard-nosed IP model can get in the way."

Future plans

Joe's next hurdle is to prove the technology can work in practice. His algorithm is a good start to the research, and he is aware that other organisations, some private, may come up with their own demand management strategies. Joe plans to pilot a working model of his technology over the next two years.

Name	**2OC**
Location	Bath, England
Sector	Energy
Employees	Three
Date started	2005
Funding	2OC's founders have spent £800,000 of their own money. The Carbon Trust and DTI turned down funding proposals. Technology partners include BOC and Cryostar, and the project is being taken forward through a joint venture with the National Grid.
Potential impact	If geo-pressure were fully exploited at pressure reduction stations in the UK to generate electricity, it would add 1 GW of electricity generation capacity to the UK's network by around 2010, and save one million tonnes of carbon per year (3.7 million tonnes of CO_2e) – equivalent to the amount of carbon emitted by the whole of the National Health Service.[83]
The concept	2OC's technology creates clean energy from naturally occurring geo-pressure traveling through the gas grid. 2OC aims to adapt a proven geo-pressure technology for use in the UK. The technology has been used abroad to a limited extent.
Brief description	Geo-pressure electricity generation exploits naturally occurring pressure from the ground. Extreme temperatures at the Earth's core create heat and pressure, which emerge whenever there is a natural or man-made outlet. This is a source of either geothermal energy (heat and steam) or geo-pressure energy (pressure). The UK is well-placed to capitalise on geo-pressure energy because most of the infrastructure required already exists. Natural gas circulates around the gas distribution system largely through geo-pressure energy – the natural pressure that emerges from the ground along with the gas. At various points in the gas distribution system, geo-pressure is removed from the system at pressure reduction stations. The pressure is reduced by squeezing the gas through a valve. However, this means that the geo-pressure is not exploited. To avoid this wastage, a small turbine can be installed in the pipeline at the pressure reduction station to perform the same function as the valve. As the pressure is reduced within the system, the turbine spins, and electricity is generated. It is then connected to the grid in the same way as other forms of generation. This allows full use to be made of the energy potential of geo-pressure. No fossil fuels are burned in the process, so no carbon dioxide is generated.
Progress to date	**2004:** Michael Edge and Andrew Mercer went looking for a project that would be good for the environment, reduce carbon emissions and make money. Their shortlist included solar PV in the Sahara, chlorine processors for fertiliser and large-scale tree planting. Through Footdown, a coaching organisation for entrepreneurs run by Andrew Mercer, they met Nigel Hunton, Chief Executive of BOC, who told them about a piece of kit developed by Cryostar in Switzerland. After visiting the factory and seeing a turbo expander – essentially a turbine fitted within a gas pipeline which could be used to generate electricity – they decided to try bringing it to the UK

83. Figures on NHS energy use from the Climate Change Programme Review consultation document, Defra, 2004.

2005: As estimated costs rose, Michael, Andrew and Nigel went looking for public funding. They realised that geo-pressure would not compete with the cheapest form of electricity generation in the current gas-fired or coal-fired centralised generation market because of the changes needed to energy infrastructure, particularly the cost of hooking up to the National Grid.

They turned to government to see what support was available to develop their low-carbon business. Funding for a demonstration plant was refused. 2OC did not qualify for any funding or support under energy efficiency criteria.

2OC instead decided to certify geo-pressure as a source of renewable energy. They obtained a legal opinion from Norton Rose that geo-pressure was eligible for accreditation under the Renewables Order (RO), and could therefore claim Renewables Obligation Certificates (ROCs).

December 2006: Ofgem granted accreditation of 2OC as a renewable resource. Any geo-pressure plant, once operational, can now use the mechanism of the RO to sell ROCs alongside electricity, therefore effectively selling at premium prices alongside renewables like wind power.

Barriers encountered

The tax framework and support structure within government – grants and price support – did not fit the 2OC model. 2OC is not strictly an energy-saving device, and it isn't about energy efficiency. In addition, it was not considered renewable, as it did not fit existing categories used by DTI and Ofgem.

Banks such as Fortis, who back renewable energy, warned that they would not fit into the usual funding structures. DTI expressed concerns about any device on a fossil fuel network being classed as 'renewable'. The renewables industry worried about a potentially large source of generation competing for essential funding and price support.

Most agreed that it was a good idea – they accepted that CO_2 free electricity was what was needed – but no one group had the incentive to take it further.

Future plans

Today, the first geo-pressure station is about to be installed, through a joint venture with the National Grid. By 2014, 2OC expect to have rolled out the technology across the gas grid.

Name	**SolarStructure**
Location	London, England
Sector	Renewable Energy
Employees	Five people currently working on the idea (none is full-time)
Date started	2003
Funding and support	Original research on solar cells was funded by a DTI Smart award. NESTA gave £30,000 to support product development. Imperial has provided incubation services. A larger corporate partner will support the full-scale product model.
Potential impact	One square metre of commercial or public space is estimated to use 145kWh/year. In London, 40 per cent of all carbon dioxide emissions are expected to come from this source.
The concept	We have only just begun to exploit the potential of the sun as a renewable energy resource. SolarStructure has developed a product for use in buildings with vertical, transparent facades, perfect for skyscrapers or large domes.[84]
Brief description	The SolarStructure product looks like a high-tech Venetian blind, but rather than blocking the sun, it harnesses its power to produce electricity and potentially hot water for the building. Light comes into the building through the nearly transparent blind, which is installed between the double glazing on all but the north side of a building. The blinds remove the heat to generate electricity, but allow in the scattered light, so there is less need for air-conditioning and lighting. The blinds automatically reorient to generate the most power, and integration technology allows the building to intelligently reduce electricity demand as more is being generated. Energy is either stored locally or used immediately. It can provide between 50 and 100 per cent of the building's needs, depending on location and the relationship of the façade to floor space. Any surplus goes back to the grid. SolarStructure technology does not need to go on the roof, like solar panels, so it provides the perfect way to capture sunlight in northern or southern climates. It opens up a whole new category of building to solar generation. Further gains could be made through carbon credits and feed-in tariffs.
Progress to date	**2004:** Massimo Mazzer, a Senior Researcher at the Italian public research institution National Research Council (CNR) and visiting scientist at Imperial College London, and Nigel Foan, a process equipment and facilities manager working for the Centre for Integrated Photonics (CIP) in Ipswich, won a DTI Smart award. They used the grant to develop the highest performance solar cell available at the time. The scientists began discussing market opportunities for a product developed from the solar cells. Soon after, NESTA invested £30,000 to support product development. **January 2005:** Imperial Innovations, the technology transfer company of Imperial College, encouraged SolarStructure to apply for additional funding to The Carbon Trust, which was investing in Imperial as an incubator of low-carbon technology. Their application was turned down. "Our application sat squarely in their high focus, high application area. Peer review was successful, but in the final stage, for some reason it was not accepted. This was a big

84. M Mazzer, K Barnham, T Green, N Foan, T Willingham, B Clive, N Glover (2006), Combining Architectural Modernity with Energy Harvesting in Transparent Facades, Presentation for Solar Cities, Oxford.

disappointment," said Nigel. The team followed up with a second application to the Carbon Trust, which was also turned down.

January 2006: Neil Glover, a buildings integration expert joined the team. His expertise filled the final gap in the development of the product. The team began looking for a partner to build a demonstrator, in order to prove that the idea was deployable.

Barriers encountered

The academics and experts involved in the SolarStructure project hold positions not solely within Imperial University – their work comes from a mix of company experience and working in other universities. As a result, the question of intellectual property was a real stumbling block. Should Imperial Innovations be able to file a patent on behalf of the university and own the intellectual property rights? Or should the individual scientists own the IP? Or somewhere in between? This debate played out for a year or more and slowed progress considerably. It has now been resolved.

SolarStructure did not want to look for venture capital funding. They instead wanted a strategic partner who could help prove that a scale model of the product would work in the market. This stage of reducing product risk was difficult to undertake in the UK, where the team found few strategic partners with the expertise they wanted.

Future plans

Continuing discussions with larger corporate partners.

Name	**Plan Vivo**
Location	Edinburgh, Scotland
Sector	Carbon finance and research
Employees	One employee at BioClimate and Development in Edinburgh. A few full-time people work on administration and project management in each country, with other technical advisors and community members involved on a regular basis.
Date started	1996
Funding	University of Edinburgh and the Department for International Development originally supported Plan Vivo. It is one of a range of carbon management approaches now managed by the Edinburgh Centre for Carbon Management. ECCM merged first with Greenergy, the leading independent UK supplier of low carbon fuels, and more recently with ESD (Energy for Sustainable Development).
Potential impact	Deforestation of millions of hectares each year causes nearly 25 per cent of carbon dioxide emissions from humans. Reforestation, replanting and management of forests can increase carbon storage by 70-120 tonnes of carbon per hectare. Plan Vivo projects have sold more than 260,000 tonnes of CO_2 Verified Emissions Reductions (VERs) to date, and have big expansion plans that could dramatically increase their impact over the next decade.
The concept	The Plan Vivo System is designed to create the conditions for long-term sustainable development. The programme was initially developed as an AIJ (Activities Implemented Jointly) initiative under the United Nations Framework Convention on Climate Change (UNFCCC). A simple modular approach allows individuals and communities in the developing world to create their own land use plans for carbon sequestration. The offsets from these are then sold in global carbon markets.
Brief description	Richard Tipper developed Plan Vivo out of his research at Edinburgh University on forestry and economics. Farmers, often with the help of local partner NGOs, develop 'planes vivos' – 'work plans' – that fit with their communities' priorities. These plans can then be registered with the not-for-profit BioClimate Research and Development (BR&D), which monitors the work, and carbon offsets can be sold onto the market. Farmers are paid once they have shown progress on the plans. Currently, Plan Vivo is operating in Mexico, Uganda, Mozambique and India. The largest and longest-running project is Scolel Te in Mexico, involving around 3,000 participants and 5,000 hectares of reforested land. Over the lifetime of the project, some 250,000 tonnes of carbon have been saved and a couple of million dollars have gone back into the local economy. Generally, drop out rates have been as low as five per cent and replacement farmers allow all carbon targets to be met.
Progress to date	**Early 1990s:** Richard was involved in a World Bank reforestation project in Mexico, and farmers suggested they should be able to develop their own plans for how to use donated trees. Richard wanted to find a business model that could sustain this bottom-up approach to development. The Department for International Development (DfID) funded the forestry research for Plan Vivo, and Edinburgh University agreed to let the intellectual property from the research be owned by the non-profit. **1996:** Plan Vivo began its pilot stage.

1997: The first carbon offsets were sold to Formula One, an ongoing partner.

1998: The Edinburgh Centre for Carbon Management was spun out of the university in 1998. The Plan Vivo System is now also managed independently by the not-for-profit BioClimate Research and Development (BR&D).

2001: Plan Vivo began selling offsets to World Rally Championships.

2002: From 2002, Plan Vivo has been operating in commercial mode. Companies like the Carbon Neutral Company in the UK and others have bought credits on behalf of individuals and organisations, from Pink Floyd to the World Economic Forum.

Barriers encountered

The process of identifying communities, planning, carbon accounting and verification is costly and requires cooperation with local governments and NGO partners in the countries of operation. There are political and social risks throughout set-up and monitoring.

It is impossible to eliminate risk from forestry projects like these. "Unlike renewables projects, Plan Vivo is still experimental. We can't guarantee that a tree will grow for 100 years. It's aspirational. We have to be open about that," says Richard.

Although the Clean Development Mechanism under the Kyoto Protocol allows developed and developing countries to cooperate to reduce carbon, land-use projects have proved controversial because of their inherent riskiness. For small-scale projects, the barriers to entry are high. "When we started these demonstration projects, people were asked by the World Bank what their Standard & Poor's rating was – are you triple-A listed? - and people had no idea what they were getting into." The market may be at risk if demand for these small-scale projects does not grow. It may also be hampered by the demands of Government departments like Defra for risk-free verification systems for carbon offsets.

Future plans

ECCM continues to look for funding opportunities to secure demand for future Plan Vivo projects. Richard is looking for private finance to guarantee the market for up to one billion tonnes of carbon over the next 10 years.

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